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THE OVERCOMING OF DISTRACTION AND OTHER RESISTANCES

BY
JOHN J. B. MORGAN

ARCHIVES OF PSYCHOLOGY

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R. S. WOODWORTH

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PREFACE

In the spring of 1913, the writer of this monograph began some minor investigations concerning the effect of disturbances of various sorts upon mental work. These preliminary experiments led to the attack of the problem on a broader basis. The quality and quantity of the work done in the first experiments showed little or no effect from the disturbances, but before concluding that such disturbances were entirely uninfluential we determined to give the thing a more thorough test. The apparatus used in the beginning required a short intermission between each minute of work; a new mechanism was therefore devised that would permit constant work for an indefinite period. As the disturbances had been comparatively weak, it was decided to use as severe disturbances as could be gotten and then after we had discovered the effect of these to reduce the intensity. As will appear later, any reduction proved unnecessary and useless. Finally we determined if no effect could be discovered in the time and accuracy records to use any test available to ascertain if there was any effect at all from disturbing influences.

Such a test as we proposed required rather elaborate and very accurate apparatus and so we need make no apology for the somewhat lengthy and detailed description of it. Its construction occupied a period of six months, but after once completed was of such a nature that it gave perfect satisfaction and the records throughout are highly reliable.

After our work on the main part of the problem, experiments of a different nature were carried on to corroborate the conclusions reached. The apparatus for these was simple and will be described briefly in connection with the experiments. The work was completed in the fall of 1915.

It is with great pleasure that we acknowledge the advice and encouragement received from Professors Woodworth and Cattell and Dr. Poffenberger. We wish also to thank those who were so kind as to work as subjects under conditions that were far from inviting.

John J. B. Morgan.

Columbia University,
New York City.

40901

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THE OVERCOMING OF DISTRACTION AND OTHER RESISTANCES

CHAPTER I

Introduction

I. *Statement of the Problem*

The setting of a psychological experiment has always been of recognized importance. Since much of the technique of experimental psychology was taken bodily from the other sciences, especially physics, it was regarded as a truism from the start that the situation created for any experimental problem had to be kept as nearly constant as possible before the conclusions could have any claim of validity.[1] It did not take long to discover that in spite of the utmost precautions to maintain an invariable situation, even though these precautions far exceeded those required in other sciences, the responses of the human reagent exhibited an enormously greater variability. While mathematics has been used to take care of variability to a large extent and has enabled psychology to arrive at conclusions in spite of irregularities in response, still there has been an unceasing effort to sift down the causes for this variability.

At first these variations were divided into groups according to the influences exerted by the supposed faculties of memory, emotion, will, attention, and the like. Experimental psychology then sought for a more exact formulation of each of these concepts and has studied how each influences activity. In some directions experimentation has been more successful than in others, but even in those phases in which some success has been achieved, much still remains to be solved. One handicap to progress has been lack of agreement in definition, an example of which is the work on attention. It has been defined in a multitude of ways, and we seem as little near agreement now as ever. Experimental work instead of seeking to sift down facts has been used to support one theory or another.[2] The most recent investigations on the measurement of attention illustrate this. Geissler[3] and Dallenbach,[4] starting with the hypothesis that attention is sensory clearness, devise an experiment which shows a correlation between grades of clearness introspectively determined and accuracy of judgments; concluding from this that their hypothesis was correct, since the only way to measure clearness is introspectively, therefore introspection must be the only measure of attention. On the other hand Woodrow,[5] taking the hypothesis that attention is an equivalent to preparedness of the nervous system to react to a stimulus, shows a correlation between the length of the preparatory interval and reaction time, which by his definition is due to the amount of attention, and hence concludes he has a measure of attention.

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[1] Fullerton and Cattell, "On the Perception of Small Differences," 1892, p. 152.

In this investigation we have no theory that we wish to demonstrate, we simply wish to investigate phenomena. Our endeavor will be to discover if possible the way in which a subject will react to irrelevant noises which are produced while he is engaged at some task. It is only a part of the problem which concerns the influence of the factors in a situation in which a reagent is placed upon his response. It is the question whether the stimulation of the sense organ of hearing will have any effect upon the performance of a task which requires in no way the use of this particular organ.

A problem need have no direct practical significance in order to be of value to science, to be of interest to the scientist, or to be worthy of investigation; but if it has practical importance it is in no wise discredited thereby. Every reader will see at once the importance of the problem of the influence of irrelevant noises upon mental work. We all know that in the reading of a peculiarly interesting book we can become entirely oblivious to every thing about us, even to severe noises. But not one of us will seek a particularly noisy place to take our reading, no matter how interesting it may be. When we enter a reading room we are confronted by the sign, "SILENCE." If we have some hard mental task, noise becomes really distasteful to us. It is then an important problem to determine just what the effect of a situation replete with irrelevant noises is upon our performance. If it is merely a foolish fancy with which we are obsessed when we desire quiet, it is well that we know it. If noise is a hindrance, can it be overcome? If so, at what cost? These and many other questions are worthy of solution. We may not answer all or any of them, but our problem is to make an attempt to do so.

---

[2] For theories of attention see:

Hamlin, A. J., "Attention and Distraction," *Amer. Jour. of Psychol.*, 1896, *8*, 3–66.

Dürr, E., "Die Lehre von der Aufmerksamkeit," Leipzig, 1909.

[3] Geissler, L. R., "The Measurement of Attention," *Amer. Jour. of Psychol.*, 1909, *20*, 473–529.

[4] Dallenbach, K. M., "The Measurement of Attention," *Amer. Jour. of Psychol.*, 1913, *24*, 465–507.

[5] Woodrow, H., "The Measurement of Attention," *Psychol. Rev., Monograph Suppl.*, 1914, *17*, pp. 158.

II. *The Method.*

The method of procedure in such a problem as this is a very important consideration. Ordinarily where it is desired to find the effect of a certain condition or circumstance upon a subject's performance, tests are made under normal conditions and compared with the results of tests made under conditions where the factor under investigation is included. If the factor has any effect it will be shown, so the supposition is, in the results. Absence of difference in the amount of work done correctly, in equal time intervals under different conditions, shows that the factor has no influence upon the task. Such conclusions are possible only on the assumption that the subject does his best in both cases. Although this is not plainly stated by some writers, it is tacitly assumed; by others it is boldly stated. For instance, Thorndike says: "In ordinary mental work one does not work throughout at one's possible maximum, so that a spurt is easily possible. In experimental work, when the subject is required to work throughout at maximum possible efficiency, such a spurt can come only if the subject has deliberately disregarded instructions, or if the knowledge of the approaching end releases forces over which he had no control. The latter is apparently possible, various external stimuli, such as other competing individuals, applause and the like, being apparently able to add a reinforcement beyond what a subject's own determination can summon."[6] While in the last statement he admits the possibility of being spurred beyond one's apparent best, he (as well as others who have worked on this line) ignores this consideration in experiments upon which it might have a large bearing.

We too went to work with this assumption, that a subject's best under one set of conditions equaled his best under other conditions. Our main experiment is a rigid test of this assumption and it seems from our results that it is wholly unwarranted. A subject is never working to the last notch, and if the proper incentive comes it is always possible for him to work harder. The way in which the ordinary experiment on the effect of some factor upon work is conducted is somewhat thus: The subject under normal conditions is assigned a certain task which he does at his best; the factor to be tested is then introduced and the subject works again at the same task; the factor is then removed and another test made under normal conditions. The subject is more or less aware of the change in the conditions. If he is fully aware of it he deliberately sets about to combat it, endeavoring to show the experimenter that such a thing cannot bother him. If he is not aware of it directly, he is conscious that the work proceeds with greater difficulty; which, with the consciousness that he is being tested, makes him put forth unusual effort to do as well as he did before. We do not state this as a presupposition to work upon, but as a result that has appeared from this experiment. We state it in the introduction so that the reader will more readily grasp the significance of the results of the first experiment.

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[6] Thorndike, E. L., "The Curve of Work," *Psychol. Rev.*, 1912, *19*, 173.

III. *Historical*

Much of the work that has been done on this line has been in connection with the problem of attention. Some work has been done with rhythmical sounds, but as we have endeavored to exclude rhythm we are not directly concerned with this. Since noises have been used in efforts to measure attention by the "distraction method", any review of the work on the effect of noise will take us into the literature on the measurement of attention, and hence will be more or less involved in theoretical problems. As a complete history of this problem may be found elsewhere,[7] we will limit our account to the work that bears directly on our problem, that of noise or sound disturbance.

1. *Noise and Reaction Time.*

As early as 1874 Wundt[8] had studied the effect of noises upon reaction time. He continually revised his statements and the report he gives in the later editions of his work may be taken as fairly expressing his conclusions. He thinks that the disturbing stimulus may be in the same sense field as the stimulus to which the reagent is to react, with the condition that there must be a clear distinction between the two, so that no confusion can arise, and one be mistaken for the other; or it may be in a different sense field. This condition which he lays down, though evidently essential, has not been always borne in mind, as our treatment of later investigations will show. He also shows that the order of presentation of the disturbance and reaction stimuli is important. As the following figures submitted by him show, if the disturbance comes with or after the signal stimulus, the result is as though there was no disturbance. If the disturbance comes before the signal the reaction time is always lengthened.

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[7] Geissler, L. R., "The Measurement of Attention," *Amer. Jour. of Psychol.*, 1909, *20*, 473–529.

[8] Wundt, W., "Physiol. Psychol.," 4th revised ed., 1893, pp. 353–358.

SOUND EXPERIMENT

	Median	Max.	Min.	A.D.
Disturbing noise with or after signal	176σ	237σ	140σ	*8*
Disturbing noise before the signal	228σ	359σ	159σ	*12*

LIGHT EXPERIMENT

	Median	Max.	Min.	A.D.
Disturbing noise with or after signal	228σ	284σ	158σ	*17*
Disturbing noise before the signal	250σ	291σ	212σ	*23*

His figures indicate much more disturbing effect when a noise disturbance is used with a sound reaction stimulus than when a noise disturbance is used with a light reaction stimulus. This seems to emphasize even to a greater degree his statement that there must be a clear distinction between the disturbance and the stimulus used.

Obersteiner,[9] experimenting on one individual only, found a prolongation in reaction time due to the effect of a music box playing "softly" in the vicinity of the subject: The normal time of this subject was 100 sigma (A.D. 11 sigma), with noise disturbance it was 141.5 sigma (A.D. 16.6 sigma). Even if it could be shown that his technique and procedure were faultless his figures would demonstrate nothing since he had but one subject and that one evidently not normal in his reactions.

Cattell,[10] making experiments on reaction using different distractions, found that sound did not act as a distraction. His explanation of this fact is that "reaction is an automatic act, only needing the activities seated in the cortex to prepare its way. A noise did not . . . so disturb the subject as especially to interfere with the placing in readiness of parts of the brain concerned in making the reaction." He explains the disparity of Wundt's results with his own on the basis that Wundt's subjects in all probability had not learned to make the reactions automatically.

Over against Cattell's work stands that of Swift.[11] His procedure is more like that of Cattell than like that of Wundt. Both he and Cattell used metronomes for disturbances, while Wundt used a single sound coming at a certain period in relation to the stimulus signal. Although they used the same disturbance and somewhat the same procedure their results are contradictory. In the case of muscular reaction Swift found a lengthening by 19 sigma of reaction-time, due to the disturbing noise. This result was obtained when the attention was directed to the reaction, effort being made to ignore the disturbance. With the attention fixed upon the disturbing sound the difference due to the disturbance was 48 sigma. He also made some experiments in reactions where choice between two movements was necessary. The subject had to discriminate between the click of two weights and a falling ball, the first finger reacting to the former and the second finger to the latter. The disturbance was caused by a metronome clicking 120 times per minute. His results in this case were:

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[9] Obersteiner, H., "Experimental Researches on Attention," *Brain*, 1879, *1*, 447–8.

[10] Cattell, J. McK., *Mind*, 1886, *11*, 237–242.

[11] Swift, E. J., *Amer. Jour. of Psychol.*, 1893, *5*, 5–17.

Normal,	Attention to reaction	179 sigma	A.D. 21
Disturbance,	" " "	197 "	" 25
"	" " disturbance	265 "	" 27

Todd[12] found that a sound given some time before a reaction lengthened the reaction time, but given simultaneously with the signal stimulus shortened the reaction time.

It is evident that the disagreement among the different investigators will permit of no very definite conclusions as to the effect of noises upon reaction time. One thing that seems to have some weight of evidence is that the more automatic the action the less will be the effect of the disturbance. Cattell assures us that the reactions of his subjects were automatic, made so by sufficient practice. Swift gives us no such assurance, which may account in part for the difference in his results. Besides, Swift's lengthening due to the disturbance was only 19 sigma, and if such a factor as practise does enter such a small difference would not be of great significance.

In Todd's experiment the same signal was used as a disturbance that had been used in other experiments as a reaction signal, the same subject serving in both. To give this as a distraction would require that the subject inhibit a reaction to which he was accustomed upon hearing that signal and this would interfere with prompt reaction when the proper signal was given. If Todd had used a noise irrelevant to any of his reaction work he might have gotten different results.

It seems safe to say, on the whole, that an unlearned or choice reaction is lengthened by irrelevant noise stimuli.

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[12] Todd, J. W., "Reaction to Multiple Stimuli," *Archives of Psychol.*, 1912, *25*.

2. *Effect of Noises on Simple Processes other than Reaction Time.*

Bliss[13] and De Sanctis[14] both worked on the effect of noises upon tapping movements. Such an experiment is not of the nature to give very definite results, and their conclusions are in every case equivocal. Both used metronomes and Bliss used in addition a shrill whistle. Bliss after acknowledging the lack of results with the metronome shows on curves where the whistle was blown and the consequent irregularity. The irregularity is certainly not very marked and were one given the curves without the marks showing where the whistles were blown and told to mark the points of greatest irregularity, it is not likely the points could be selected properly. Such simple movements show no definite effect of disturbance by noise.

3. *Noise and more Complicated Processes.*

Boas[15] tried to determine the effect of a disturbing noise on the determination of the brightness limen. Music was used and the observer instructed to attend to the music as well as to the task of discrimination. He found that the observer attended to the distraction ignoring the brightness task.

Darlington and Talbot[16] experimented upon the effect of a phrase of music upon the judgment of lifted weights. They found that the effect of the music was to facilitate attention, and did not serve as a distraction. They concluded that music has a dynamogenic effect, although they found no relation between this effect and pitch.

Tanner and Anderson[17] used as a task the determination of changes in color due to the effect of a tuning fork, as well as other disturbances. They concluded that the sensations were intensified by the addition of sensations from other sense organs.

Angell[18] in connection with an investigation on the value of images in forming judgments of similarity or difference, used seven different disturbances, three of which were: counting metronome beats, listening to interesting reading, and the discrimination of clangs differing by 8, 4, and 0 vibrations. His object was to see if he could by such means efface images of the first of the pair of clangs to be compared. His results were negative. He found no definite difference between judgments with and without disturbances. His conclusions have more of a theoretical bearing on the problem of imagery than on that of disturbance by noises.

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[13] Bliss, C. B., *Stud. from the Yale Psychol. Lab.*, 1893, *1*, 50.

[14] De Sanctis, S., "L'Attenzione e i suoi disturbi," Rome, 1896. Also *Zeits. f. Psychol. u. Physiol. d. Sinnesorgane*, 1898, *17*, 205–214.

[15] Boas, *Pfluger's Archives*, 1881, *26*, 496.

[16] Darlington, L., and Talbot, E. B., "A Study of Certain Methods of Distracting the Attention," *Amer. Jour. of Psychol.*, 1898, *9*, 332–345.

[17] Tanner, A., and Anderson, K., "Simultaneous Sense Stimulations," *Psychol. Rev.*, 1896, *3*, 378–383.

[18] Angell, F., "Discrimination of Clangs for Different Intervals of Time," *Amer. Jour. of Psychol.*, 1900, *12*, 50–80.

Geissler[19] used noise among other disturbances in an attempt to measure attention in terms of clearness, using as a task visual discriminations. He concludes that even the "most complex combination of distractors after a few days work were unable to induce great variations of attention. Instead toward the end of the whole group, most of the normal series were actually performed at a slower rate than the distraction series."

Dallenbach[20] followed Geissler's experiment using, instead of visual discrimination, auditory discrimination. Neither experiment was of a nature to discover with any accuracy the effect of noises. The procedure consisted in producing various conditions of disturbance while the subject was doing the assigned task, a record being taken in terms of time (or amount done) and of the accuracy of the performance. Then after each experiment an introspective measure of the clearness of the content discriminated in the experiment was obtained. Finally a correlation was calculated between this clearness scale and the speed and accuracy of the work, and because this correlation was rather high the conclusion was drawn that the true measure of attention is a subjective scale of clearness. Such a conclusion presupposes that the amount and precision of the work was influenced only by changes in attention. This could not be known unless all practise, fatigue and feeling factors were eliminated. But supposing that the experimenters had eliminated all these (which they certainly did not), why not take the amount and precision of the work as a measure of attention directly and not by a roundabout procedure, involving endless difficulties, adopt a measure which is from the very nature of it much less precise? Dallenbach used the distractions to procure changes in the performance of the subject but since he finds no definite correlations he concludes that disturbances have no reliable influence. An inherent difficulty prevents him from giving any precise answer as to the effect of the disturbing noises. In an earlier section we called attention to the fact that Wundt lays down the rule that if the disturbance is in the same sense field as the task it must be of a distinct sort. Dallenbach's task was to note the point of time and rapidity of changes in pitch and intensity of a tone made by a Stern variator, at the same time using as disturbances, sounds varying from a metronome to a graphophone. Inaccurate judgments in such a situation would, in some cases at least, arise from confusion, the confusion would cause a report of a low degree of clearness, and of necessity the confusion would also cause a poor score. The correlation between clearness and precision would thus be increased and of course help in the endeavor to show that clearness is the measure of attention.

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[19] Geissler, L. R., "The Measurement of Attention," *Amer. Jour. of Psychol.*, 1909, *20*, 473–529.

[20] Dallenbach, K. M., "The Measurement of Attention," *Amer. Jour. of Psychol.*, 1913, *24*, 465–507.

In conclusion: It is probable that reaction time that is not automatic is lengthened by noise disturbance, automatic reaction times not being affected.

Of the effect of noise disturbances on higher mental processes, all that can be said is that there is some evidence of a dynamogenic effect, the stimulation of one sense organ facilitating the functioning of another. This conclusion however is not universally accepted,[21] and needs further evidence.

IV. *Outline of the Experiment*

From the results of the work upon the effect of noise it seems evident that certain methods are unproductive. The study of its effect upon judgments of various sorts has been very uncertain and irregular, due perhaps to the fact that the judgments can be made in the intermittent period of any disturbance that is not absolutely continuous. The results also show that any task which could be made automatic by practise is unsuited for use in an experiment to ascertain the effects of any disturbing influence.

We therefore endeavored to get some test which could not be practised to the point where it would require no cerebral direction, and which yet had little practise effect. The card sorting test seemed a good one for the purpose,[22] but had the disadvantage that it did not permit of accurate measurement. An arrangement was consequently devised that would require a similar task but one which could be measured. It was planned to have ten different letters (or numbers) exposed in a chance order as fast as the subject could react to them and in an endless series. His response consisted in pressing a key corresponding to the letter or number seen. These numbers were arranged on the keys numerically so as not to require the learning of their position, since everybody is familiar with the sequence 1, 2, 3, 4, 5, 6, 7, 8, 9, 0. As the subject was told to react always with the same finger, the correlating of a certain

[21] Binet, A., *L'Annee Psychol.*, 1900, *6*, 562.

[22] Jastrow, *Psychol. Rev.*, 1898, *5*, 297. Seashore, C. E., "The Psychergograph," *Studies in Psychol. Univ. of Iowa*, 1902, *3*, 1–17.

number with a particular finger was eliminated and we had a simple procedure which could not be learned and which required the same process the last time it was made as it did the first. One must look at the exposure opening to see what number was exposed, look at the keys and select the proper one and react with the first finger of the right hand. The order was so varied that it could not be memorized, and the subject kept busy for an indefinite length of time.

While he was thus busy noises were introduced and as each response of the subject was being recorded the exact effect of this noise was measured. The subject was placed alone in a room and was not disturbed by the experimenter or by any machinery. The only machine in the room consisted of the exposure apparatus, which worked only at his touch of one of the keys.

Various procedures, tried in an effort to eliminate irregularities, will be described in order to show the comparative merit of the one used in the later experimentation. It was found advisable to take other records besides those of speed and accuracy, for reasons which will appear as we progress with the report.

Great care was taken to have the apparatus in good working order.

The majority of the subjects knew nothing of the nature of the experiment, or of experimental psychology. They were brought in from outside or from other departments of the university through the assistance of friends. They were placed in the room, instructed how to react to the stimuli and left to themselves. They were told that records were being taken of their speed and accuracy, but they knew nothing about the noises that were to be introduced. Our object was to see how a naive subject would react to a certain situation. Several trained subjects were also used, none however trained in this particular experiment.

CHAPTER II

APPARATUS

AN important condition to the successful conduct of an experiment such as the following consists in properly designed and constructed apparatus. In order to make clear this fact a brief description of the nature of the procedure of the experiment might not be out of place here. It was desired to have the subjects alone in a room seated before an exposure apparatus which would present to them material in varied order and just as fast as they could respond to it. The subject's response to these presentations would consist in pressing one of a number of keys, which must be connected with a recording apparatus that would register both speed and accuracy of response. Furthermore, it was required that the task be so designed that the subject should be kept at work for a considerable length of time. During the course of the experiment disturbances were to be introduced and all these would have to be arranged so as to be controlled from outside the subject's room.

I. EXPOSURE APPARATUS

Probably the most important instrument in such an experiment as this is the exposure apparatus. It was necessary, (1) that each exposure remain in place until the subject responded, and that this response cause the immediate appearance of the next exposure, which would in turn remain until responded to by the pressure of the corresponding key. (2) In the second place it was necessary that the series be of such a length and arrangement that though it was repeated the subject would not be able to memorize the sequence. (3) It must make little noise. It was not considered that it must be absolutely noiseless in the same sense as a visual exposure in reaction time work, but there must be no noise except the click at the pressure of the key. (4) It must respond easily and quickly, (5) and finally it must work every time.

There are a number of commercial instruments which expose material at regular intervals. With such an arrangement the subject must react just as quickly as the exposures appear or he will make omissions which must be counted as errors. It was desired to get the record as largely as possible in terms of time, and this could only be done by allowing the subject to set his own pace and designing an instrument whose speed of action would depend upon the speed of his response.

A typewriter has been adapted to meet such requirements.[1] It however was not entirely suitable for the present investigation. It gives only a short series, which is repeated each time the carriage is shifted. Since it begins at the same point this series may be readily memorized, in part at least. Besides it was not suitable for obtaining a record of the pressure exerted upon the keys, without elaborate changes, and since we planned to take this record we discarded the typewriter for something more suitable. The writer worked with a mechanical apparatus in some previous investigations, but found that it did not work as easily as was desired. If the action of the instrument depends upon the proper striking of the key, as a mechanical one does, it fails to work at times, for different subjects strike the keys in different ways.

The only other hopeful type is the electrical. Of these a number have been designed and used, most of which however have a type of movement that makes their action uncertain. The operation of this type consists in a lever (*B*) operated by an electro magnet (*A*), working on a notched wheel (see Fig. 1). The movement of the lever toward the magnet turns the wheel one notch. It is stopped either by a spring (*D* and *F*) bearing upon the notched surface at another point, or some similar device. When the current

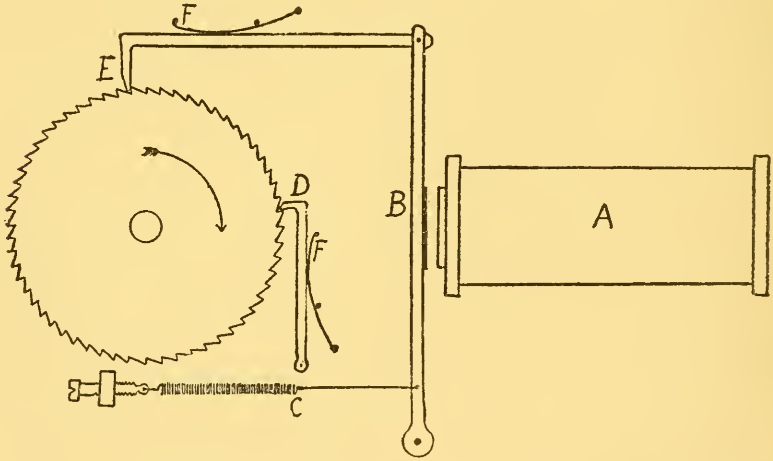

Fig. 1. Sketch designed to show the principle of an unsatisfactory exposure movement. *A*, electro-magnet; *B*, armature; *C*, spring to pull the armature back to place after it is released from the magnet; *D*, catch to hold wheel in position until moved by catch *E*; *FF*, springs to hold catches in place.

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[1] Bair, J. H., "The Practice Curve," *Psychol. Rev. Monog. Suppl.*, *19*, 1902, 15.

through the magnet is broken a spring (*C*) pulls the lever away from the magnets, allowing *E* to engage a new notch. It may be arranged in one of two ways; the wheel may be turned when the lever is pulled toward the magnets, the spring serving to pull the lever back into place and engage a new notch; or it may be reversed and the magnet pull the lever so as to engage a new notch, and the breaking of the current allow the spring to turn the wheel. Whichever method is used the difficulty is the same and it is this: The disc or cylinder, or whatever it is that must be turned in order to expose the material weighs something, consequently there is a certain inertia to be overcome in starting it and momentum to be overcome in stopping it. The adjustment of current strength, spring tension, and the device used to stop the wheel, so that they all work properly and work every time is a well-nigh hopeless task. Either the momentum will at times carry the cylinder two or three notches instead of one, or the inertia will keep it from responding at all when the spring is tight enough to overcome the first difficulty. This principle is however used very successfully in the electric counter of the Hollerith electric tabulating system because the only weight to be moved is that of the hands of the counter.

A type of movement that will allow considerable weight to be moved a certain distance and stopped quickly, that will work accurately and work every time in perfect response, is the escapement movement. It is in successful commercial operation in all clock works and typewriters, which is of itself sufficient recommendation for it. The apparatus used in this experiment was constructed on this principle, and to encourage its use in laboratories it may be said that once built it worked without fail through the entire experiment requiring no attention or readjustment.

Now for a more detailed description of it. An old clock work was used. In place of the hands was substituted a cardboard disc on which could be placed the material to be exposed. A different wheel from the one used as the escapement wheel had to be used so as to turn the disc far enough at each escapement. With this change the fundamental part of the exposure apparatus was complete. A simple sketch of the mechanism is shown in Fig. 2.

When the current is closed through the magnet (*A*), the armature (*B*) is drawn up, allowing one tooth of the escapement wheel to pass the side of the engaging lever against which it is resting, the wheels being propelled by the mainspring of the clock; the other side of the engaging lever (*E*) comes in front of another tooth however before the first one has been released, thus allowing the wheel to move only a given distance. When the circuit is broken the spring draws the armature back to its original position, one side of the arm catching one tooth before the other side releases its tooth. It can be readily seen that it is simply a matter of accurate construction to make an apparatus of this nature that will accurately perform for an indefinite period of time with little or no attention. The one used will give five thousand exposures with one winding.

The disc used in connection with this mechanism made a complete revolution in sixteen complete movements of the magnet armature. It was thought that this series was not large enough, and so the cardboard placed in front of the disc to cover all but the letter to be exposed, was made to move in a horizontal direction. This movement allowed different circles of the disc to be exposed.

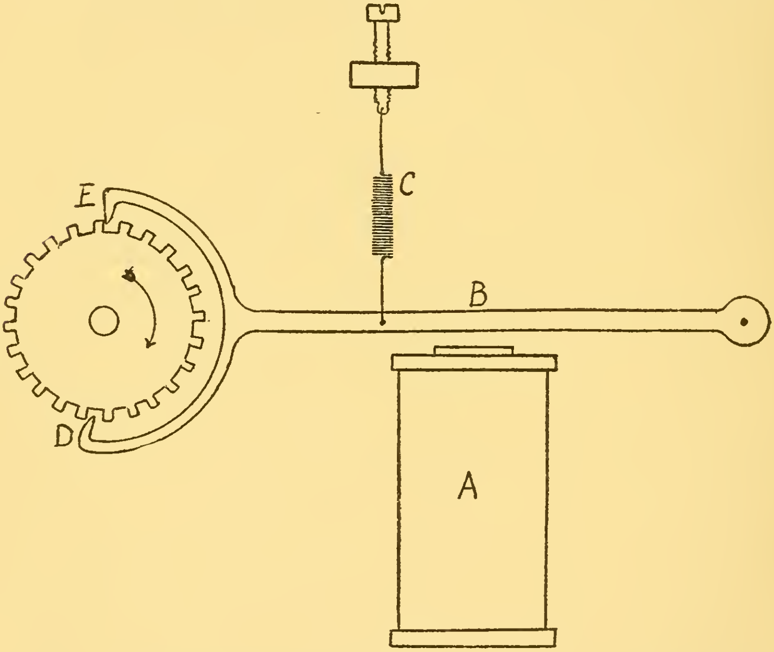

Fig. 2. Diagram of the escapement movement. *A*, electro-magnet; *B*, armature; *C*, spring which pulls the armature from the magnet when the current is not flowing; *D* and *E*, catches engaging the teeth of the gear wheel. When the armature is pulled away from the magnet the catch *E* releases its gear and catch *D* engages one on its side. When pulled to the magnet *D* releases its hold and *E* again engages.

Different circles of letters were arranged upon the disc and so a large series procured. This movement was made by the operation of an electric current upon an electro magnet, which current was closed automatically once upon each revolution of the disc. The opening occupied four different positions. If, for example, at first it occupied the extreme left position, the next move would be to the right, the second to the right, the third to the right again, the fourth would be to the left, the fifth to the left, and on the sixth it would occupy the position it did at the start. Its movement then was like that of a shuttle with however two stopping points between the extremes. There were to correspond four rings of letters upon the discs behind the screen. If the rings were numbered from one to four from the inner ring to the outer they would be exposed in the following order, 1, 2, 3, 4, 3, 2, 1, 2, 3, 4, 3, 2, 1, etc. The series would be repeated but in different orders, and as the subjects did not know the operation of the apparatus they had no definite starting point from which they could learn the series.

Furthermore, it was desirable that the task of the subject be varied. Instead of the simple task of seeing one of a series of letters or numbers and reacting by pressing a corresponding key, it was deemed advisable to complicate the task somewhat. This was done by the use of codes. For instance the letter Z might be exposed; by means of a code placed before the subject this letter would be translated to *A*; looking to another code he would translate *A* to a 2, and react by pressing key number 2. Several of these methods were used and will be described fully in discussing the experimental procedure. It is simply desired here to show the relation of these codes to the construction of the apparatus.

If such codes had been arranged and placed before the subject he possibly could have memorized the codes during the work. To avoid this a device was included for changing the codes, which device is shown in Fig. 3. One pair of magnets (*J*) was in series with key number two of the reacting keys (there being ten in all), and the other pair (*K*) were in series with key number seven. As the subject worked he would press each of these keys in their turn and thus magnetize one or the other of the magnets. If the current passed through one pair (*K*) it would release the catch (*L*) and the spring (*M*) would pull the arm away from the second pair of magnets (*J*). If the current passed through the second pair (*J*) the armature would be drawn up and held by the catch (*L*). If the arm were already engaged in the catch and the second pair of magnets received the current, it would not move. By this arrangement the arm had to be either at one end of the movement or at the other end. This was very desirable. The paper strip containing the shifting letters must always be in a position to show one code or the other. A device that would not insure this would be unsatisfactory, as it might move halfway and thus either confuse or even stop the subject's work. It could not happen with this arrangement. In brief then, the code consisted of a card containing a row of letters beneath each one of which was an opening. Behind these openings another card was moved by the magnets, at each move bringing to view a new set of letters and thus changing the code.

To sum up, the working of the apparatus is as follows: Upon every reaction of the subject the exposure disc turns one sixteenth of a revolution, bringing to the opening a new character; every sixteenth reaction the opening shifts, thus presenting a new circle of characters; and when certain of the reaction keys are pressed the code, by which the characters are translated, is changed.

II. Reaction Keys

The keys upon which the subject were to react were ten in number. They were about the size of typewriter keys and placed in one row, spaced the same distance as typewriter keys. Each key was supported upon a bar six inches long. This bar was pivoted at the center and at the end opposite the key was fitted with a spiral spring which drew the key back to place after each reaction. This spring could be given more or less tension by means of a screw, so that all the keys could easily be made to respond to the same pressure.

Various types of contacts were tried before a successful one was obtained. It was found that any type of simple touch contact was not satisfactory because if the subject made a quick response a good connection was not always made. The success of the experiment demanded that every time a key was pressed, no matter in how careless a manner, contact should be made. Mercury contacts were the only ones that could be made to do this. A point from each key, when pressed, entered into a mercury trough. The mercury in the trough was covered with oil so as to eliminate any sparking of the contacts. All the attention that these keys needed in order to insure perfect work was the occasional removal of the old oil and its replacement by a new supply. The keys were tested from time to time to insure proper adjustment of the tension springs.

III. Pressure Recording Device

One reason why the keys had to respond perfectly to every reaction was that it was planned to take a record of the pressure exerted upon them by the subject in his reactions. This was accomplished by means of the following device. All the keys were mounted on one block of hard wood. The rear edge of this block was mounted in turn on hinges and the front supported by a spring which was sensitive enough to respond to the lightest touch, and yet stable enough not to allow a rocking of the board after a reaction. Fastened to the board was a rod which was connected to the diaphragm of a Marey tambour. This tambour was joined with another which made the record in an adjoining room. This scheme worked so well that the lightest touch, even too light to move one of the keys (which worked with very light pressure), made a record, and yet with so little vibratory movement that not one of the subjects, when questioned after the experiment was finished, stated that he had discovered that there was a mechanism connected with the keys to take a pressure record.

IV. BREATHING RECORD APPARATUS

The breathing records were taken by means of a pneumograph connected with a recording Marey tambour. It consists simply of a three quarter inch spiral spring enclosed by a flexible rubber tube which is closed at each end and connected with a rubber hose leading to the recording tambour. Any movement of the body around which it is placed changes the volume of air enclosed in the tubing and makes a record.

V. RECORDING APPARATUS

(*a*) *Time and Accuracy Records*

The graphic method was used throughout the experiment. Connected with each reacting key was a separate electromagnet which operated a recording armature. All the keys were also connected through a single magnet, so that when any one key was struck it operated its special magnet as well as the one common to all. Recording by the side of this common magnet was another connected through a Jacquet time clock, recording once every second. Another magnet was connected with the keys used to put into operation the disturbances used in the experiment, and another to record the shifting of the exposure opening.

These fourteen magnets all recorded side by side by tapping a typewritter ribbon against a continuously moving paper. The paper was turned over a drum by means of an electric motor. The motor also operated a device which turned slowly the typewriter ribbon.

By means of this record the time and accuracy of the performance could be obtained. The record contained, side by side, the time line in seconds, the disturbance record, the reaction time record, and the records of the individual magnets, which gave the accuracy score. The experimenter had a table of the series of exposures as they would appear, and thus could detect erroneous reactions in the record. This whole mechanism worked automatically and after it was once started needed only to be watched to see that nothing went wrong; it allowed the experimenter to give his time to the operation of the disturbances and of the kymograph used for the breathing and key pressure records.

(*b*) *Breathing and Key Pressure Records*

The breathing and key pressure records could not be recorded on the same sheet as the speed and accuracy records, since they required smoked paper. A simple clock-work kymograph was used for these. A sufficient supply of smoked paper was prepared beforehand to take the records for a full sitting of an hour or longer. On the drums were three records: (1) the time line procured electrically by the same Jacquet clock that made the time line on the continuous roll kymograph; (2) the breathing record; (3) the record of the pressure exerted upon the keys at each reaction.

A few breathing curves and a few key pressure records were lost each time a drum was changed, but these were only a small percentage of the total number and their omission does not distort the data obtained.

VI. DISTURBANCES

It will be difficult to convey to the reader an adequate idea of the disturbances used in this experiment. An effort was made to have them severe enough to compare with those which one meets in daily life, and it may be said without the least exaggeration that they were much more severe than any which one meets under ordinary circumstances. Only sound disturbances were used. The first set were a group of noises which in actual work were always used together, changing continuously from one to another. This set comprised nine different sources in various parts of the subject's room, which was eighteen feet long, thirteen feet wide, and fourteen feet high. Their severity can be better appreciated if it is remembered that they were in a closed room of this size. They were:

1. A fire bell with an eight-inch gong, directly behind the reagent and eight feet away.
2. A bell mechanism with the gong removed and the hammer striking against a resonance box, placed behind the subject to the left.
3. Another bell mechanism with the hammer vibrating against a metal beam which ran the whole length of the room.
4. A bell hammer vibrating against the table where the subject sat.

5. A buzzer placed upon the subject's table.
6. A bell to the left in front of the subject.
7. A bell behind the subject to the right.
8. A buzzer on a tin box under the table where the subject sat.
9. A buzzer on the left wall on a resonance board.

All these were connected electrically with keys in the experimenter's room and were operated from there.

Besides this set of noises a graphophone was used. The machine was set up in the experimenter's room and connected through the wall to the horn in the subject's room by a metal tube. Metal was used to insure full transmission of the sound. The records used were six in number. Two were vocal solos, two were instrumental selections, and two were humorous speeches. In detail they were:

1. "Killarney." Tenor solo.
2. "Sentinel Asleep." Bass solo.
3. "Amoureuse Waltz." Concertina solo with orchestra.
4. "The Swiss Shepherd." Ocarina solo with orchestra.
5. "The Liars, or My Uncle's Farm." Two negroes talking.
6. "How Mother Made the Soup." Monologue.

VII. Wiring

The wiring of the complete apparatus[2] is shown in Fig. 3. Since this diagram embraces six independent circuits, for the sake of clearness it will be necessary to trace each one separately.

1. *The Signal Lamp Circuit*

Two sixteen candle power lamps (*A* and *B*) were placed behind, one over each shoulder of the subject, as he sat facing the apparatus. These were in addition to the lighting of the room, which was a single light in the middle of the ceiling. Since he worked in a dark room the subject could not see the exposure apparatus until the two lights behind him were lighted. These served then as an admirable signal for him to begin and end his work. They were operated by a key (*C*) in the experimenter's room, as may be seen in the diagram.

2. *The Reaction Circuit*

As soon as the signal was given the subject reacted to the letter already exposed. This he did by pressing one of the keys (*D*). This closed a circuit which passed from the positive side of the battery source (E.M.F.) to the magnet (*F*) which operated the exposure apparatus (*G*), through this magnet to the mercury trough common to all ten of the subject's keys (*D*), through the contact to the cable and thence to the recording magnet corresponding to the key pressed, then to the recording magnet (*H*) common to all, and finally through an electric counter (*I*) to the negative side of the battery source. The pressing of any one of the reaction keys thus did several things. It operated the exposure apparatus, bringing a new letter to view, it operated also the recording magnets and an electric counter.[3] As soon as he could the subject looked at the letter which his first reaction had brought to view and reacted to it, and so on as long as the lights were turned on.

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[2] The graphophone of course had no electric connections so that the experimenter marked on the record the beginning and ending of each performance of this instrument.

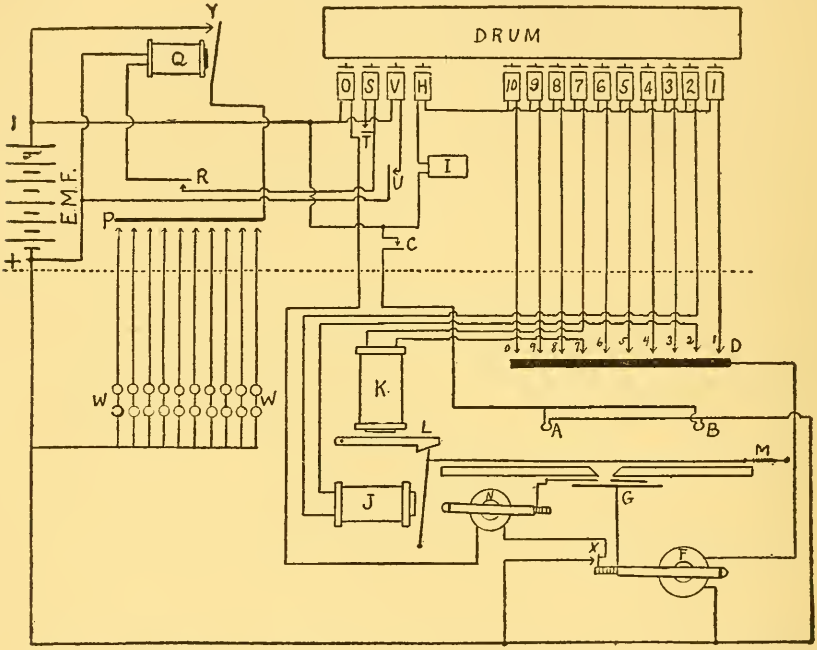

FIG. 3. Wiring of the apparatus. The dotted line represents the division between the two rooms, the lower half being the subject's room and the upper part the experimenter's. All electric contacts are represented by arrow points. Where one line passes another without making contact one of the lines makes a semicircle over the other. Where two lines meet squarely it means that they are connected. Only one battery source is shown (E.M.F.) in order to make the drawing clearer. As the circuits required currents of different strengths different sources were used, and various resistances inserted where needed. *N* and *F* are magnets operating devices whose principle of operation is similar to that of Fig. 2. The detailed explanation of the circuits will be found in the text.

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[3] This record was not used in tabulating the results. These were all taken from the graphic records. It simply served to show the experimenter how many reactions the subject had made at any point in the experiment, and guided him in the administration of the disturbances.

3. *Code Circuit*

If the key which he pressed happened to be number two, the current before going through the cable to the other room passed through one of the magnets (*J*), working the slide which changed the code. If it happened to be key seven it went through the other magnet (*K*) of this mechanism before entering the cable and changed the code in the other direction.

4. *The Screen-shifting Circuit*

Furthermore, when the disc of the exposure apparatus made a complete revolution it closed another circuit (*X*) from the positive side of the battery source through the magnet (*N*) shifting the exposure opening and through the recording magnet (*O*) back to the negative side of the battery source. This served to expose a new circle of figures or letters on the disc.

5. *Disturbance Circuits*

All the above connections were effected through the reactions of the subject. The noises (*WW*) were operated by the experimenter. Each of the noises was connected with a key and all of these keys (*P*) were connected through the contacts of a relay (*Y*). To operate a noise the experimenter closed one of the noise keys and then pressed another key (*R*) closing a circuit through the recording magnet (*S*) for noises and the relay (*Q*). This closed the relay contacts (*Y*) and set the noise into operation. In the experiments where noises were kept going continuously, as this arrangement would keep the recording magnet drawn up continuously, another key (*T*) was used to short circuit the recording magnet (*S*) and thus release the recording armature, while the relay armature (*Q*) would still be drawn up. Before the noise was stopped it was again opened, allowing the magnet to record, and thus the points where the noise began and ended were marked.

6. *The Time Line Circuit*

The time line was a series of dots on the paper a second apart. It was made by a current passing from the positive side of the battery through the Jacquet time clock (*U*) the recording magnet (*V*) to the negative side of the battery.

CHAPTER III

EXPERIMENTS WITH TIME AND ACCURACY RECORDS

I. *A Comparison of Several Tasks*

1. *Description of the Tasks.*

THE first problem attempted was to find the comparative value of several tasks, in order to see whether the noises would have a different effect as the task became complicated. Four tasks of varying difficulty were tried, all of which could be used in connection with the apparatus described in Chapter II. The ten keys were numbered 1, 2, 3, 4, 5, 6, 7, 8, 9, 0. The exposure apparatus was arranged to expose these ten numbers in chance order. In the simplest task the subject looked at the exposed letter and pressed the proper key with the first finger of the right hand.

In the second task the first ten letters of the alphabet were exposed in chance order. The subject after perceiving the exposed letter looked at a code, translated the letter to a number, and then pressed with the forefinger of the right hand the key corresponding to this number. The code was changed by the apparatus described above and so could not be memorized. The upper unchangeable part of the code consisted of the letters arranged alphabetically, while below each letter a number was exposed.

In the third task the exposures comprised the letters L M N P S T V X Y Z. Two codes were used, both being changeable. The first code consisted of an upper row with the letters L M N P S T V X Y Z and the lower the first ten letters of the alphabet in chance order. The second code had the first ten letters of the alphabet on the upper row, and numbers on the lower. The subject translated the letter from the lower end of the alphabet to one from the upper and then this letter to a number, which told him which key to press.

The fourth task was still more complicated. In this task the letters L M N P S T V X Y Z were exposed upon backgrounds of one of the three colors; red, yellow, or green. Below the exposure opening was a changeable code where the letters were to be translated to one of the first ten letters of the alphabet.[1] Above the exposure opening were three codes, one red, one yellow, and one green. Each of these codes had an upper row consisting of the letters from the beginning of the alphabet, beneath each of which was one of the numerals used on the keys. In this last task the subject had to look at the opening, note the color as well as the letter, look to the lower code and translate the letter to one of the letters A, B, C, etc., then look above the exposure opening to the code whose color corresponded to the color exposed at the opening, translate here the letter to a number and press the proper key, whereupon, as usual, the apparatus exposed a new combination to be reacted to.

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[1] After the first few experiments it was found that the letter I was confused with the number 1, and so the letters A B C D E F G H J K were used.

2. *Experiments with the Different Tasks.*

In the first experiment all four of the tasks were tried with the same subject. This subject, a woman, knew the nature of the experiment, but had received no preliminary training in it. The procedure was as follows: The subject worked about one hour on task one with no disturbance. The next day at the same hour on the same task with disturbance throughout the hour. In the same way the next two days were devoted to test two. The following two days were devoted to tests three and four, an afternoon and evening sitting being given on each day, the quiet period in the afternoons and the noisy ones in the evenings. The noises used in these experiments were the combination of nine noises described in Chapter II. Changes were made at rapid though uneven intervals from one to the other all through the disturbance hour. The results may be seen in Table I.

In calculating the results of this and all the following time records, the time was measured for every ten reactions, hence each time figure is for ten reactions. The probable errors given are the median deviations of these measures from the averages, divided by the square root of the number of cases. Since in different places a different number of measures are averaged, this method was used throughout in order to give comparable measures of reliability.

This table reveals very little practise effect in any of the tasks. In the first task the last group is actually slower than the first. We cannot explain just why this is the case but from the nature of the test it is probable that after the first several hundred reactions it became monotonous and the subject settled down to a slower, even movement. At first there was slight improvement, then after the six hundredth group there was a decline to 13.5 seconds. This speed was maintained through the remainder of the first period and likewise through the second in spite of the disturbance. It might seem at first glance that the fact that the second period shows slower time through the middle indicates the effect of the

TABLE I

Time Records of One Subject with Four Different Tasks

Task I

	Quiet		Noisy	
Reactions	Av.	P.E.	Av.	P.E.
1–100	12.3	*0.6*	12.8	*0.2*
101–200	13.6	*0.3*	13.0	*0.3*
201–300	11.9	*0.3*	13.5	*0.3*
301–400	11.0	*0.1*	13.2	*0.2*
401–500	11.7	*0.2*	13.8	*0.2*
501–600	11.9	*0.2*	13.4	*0.2*
601–700	13.5	*0.2*	13.1	*0.2*
701–800	13.7	*0.2*	13.4	*0.3*
801–900	14.2	*0.4*	13.6	*0.2*
901–1000	13.5	*0.2*	14.4	*0.2*

Task II

	Quiet		Noisy	
Reactions	Av.	P.E.	Av.	P.E.
1–100	33.3	*0.9*	22.9	*0.3*
101–200	30.2	*0.6*	24.3	*0.3*
201–300	28.2	*0.6*	25.6	*0.3*
301–400	27.5	*0.7*	24.6	*0.3*
401–500	36.7	*0.6*	24.2	*0.3*
501–600	24.2	*0.2*	25.7	*0.4*
601–700	22.2	*0.3*	24.7	*0.2*
701–800	24.0	*0.3*	24.4	*0.3*
801–900	36.7	*0.5*	24.5	*0.6*
901–1000	24.7	*0.5*	23.5	*0.3*

Task III

	Quiet		Noisy	
Reactions	Av.	P.E.	Av.	P.E.
1–100	47.4	*0.6*	40.2	*1.2*
101–200	45.5	*0.9*	41.0	*0.6*
201–300	43.6	*0.6*	41.4	*0.5*
301–400	42.8	*0.7*	41.0	*0.7*
401–500	41.6	*0.6*	42.7	*0.9*

Task IV

	Quiet		Noisy	
Reactions	Av.	P.E.	Av.	P.E.
1–100	59.7	*0.9*	44.3	*1.1*
101–200	56.6	*1.5*	45.4	*0.8*
201–300	50.0	*0.9*	46.2	*0.9*
301–400	52.2	*1.5*	45.6	*1.3*
401–500			46.6	*0.5*
501–600			50.1	*1.1*
601–650			59.7	*2.3*

The column of averages gives the average of the hundred reactions indicated in the first column. The probable errors are the median deviations of each group of ten in the hundred divided by the square root of ten. As the times were figured in groups of ten each figure represents the seconds required for ten complete reactions.

noises, but when the two periods are taken together it hardly seems the case. The first period showed the subject that the test period was rather long and so in the beginning of the second period she settled down to the steady pace acquired in the first period. For this reason it seemed that this task was not as suitable as some of the others for our purpose. We wanted a test that would require alertness on the part of the subject.

The second task likewise shows little practice effect although more than the first. After the first four hundred reactions the score is practically on a level for the rest of the hour. In the disturbance hour the subject begins at the same rate (except for a slight initial spurt) that had been attained the day before and carries this through the hour in spite of the noises.

Task three shows little difference from task two except that the absolute time is longer. We scarcely have a fair representation of the value of task four, as the subject was limited for time the first period. It seems on the whole to show a slowing up during the disturbance period, although the first part of that period shows a better record than that attained in the previous quiet period.

We reached two conclusions as a result of these tests. First, to carry on the work with all four tasks seemed of little value, since apart from the absolute differences in time three of the tasks gave the same results. As to which to adopt we had not enough data to decide. As we have said, the first seemed to require too little attention and so we decided not to use it. The next experiment will show another comparison of the second and fourth tests. As the second and third were so nearly alike in results to have used both of them would have been useless.

In the second place these results showed us that the procedure followed thus far was not likely to bring definite results. The rest period between the two sittings made the disturbance period incomparable to a large extent with the practise period. Any change in time between the two, unless very large and in a definite direction for a large number of subjects, might be due to other factors than the noise disturbance. This method was used at first because it was expected that a longer practise period would be needed. Since this work showed however that after about four hundred reactions there was very little improvement, it was decided to have quiet and noisy periods all at one sitting.

In the next experiment a different subject was used in tasks two and four, in order to try out the method of having the disturbance and quiet periods alternate in the same sitting, and also to get a comparison between the two tasks. As in the preceding, the combination of nine noises were used for the disturbances. The records are given in Table II.

In task two there is a slight improvement as far as seven hundred reactions. From there on there is practically no improvement. The record shows little effect of the noises. There is a slight decrease in speed at the beginning of each noise period followed by an acceleration, until the noises ceased. With task four the practise limit is about reached in the fourth hundred. Here we notice again the acceleration while the noises are going on and a slowing of speed after the noises cease.

This test shows clearly that the procedure here used is better than the preceding. If there is any effect of the noise on the time it will show when placed in sharp contrast with immediately preceding and folllowing quiet periods. While there seems little difference in the results of the two tasks, task four shows a little more flexibility than does two. Besides the arrangement in task four made it impossible to memorize any of the letter combinations; the complication of two sets of letters, one set of figures, and three colors

TABLE II

Time Records of One Subject with Tasks Two and Four

Task II

Reactions	Av.	P.E.
	Quiet	
1–100	18.2	*0.3*
101–200	17.6	*0.2*
201–300	16.4	*0.1*
301–400	15.9	*0.3*
401–500	15.6	*0.1*
501–600	15.3	*0.3*
601–700	15.0	*0.1*
701–800	14.6	*0.2*
801–900	15.2	*0.1*
901–1000	14.9	*0.1*
	Noise	
1001–1100	15.4	*0.3*
1101–1200	14.5	*0.2*
1201–1300	14.3	*0.2*
1301–1400	14.5	*0.1*
1401–1500	14.5	*0.2*
	Quiet	
1501–1600	14.7	*0.2*
1601–1700	14.4	*0.1*
	Noise	
1701–1800	14.3	*0.2*
1801–1900	14.3	*0.2*
	Quiet	
1901–2000	14.4	*0.2*

Task IV

Reactions	Av.	P.E.
	Quiet	
1–100	32.9	*0.4*
101–200	33.3	*0.4*
201–300	30.9	*0.3*
301–400	29.5	*0.3*
401–500	26.8	*0.5*
	Noise	
501–600	26.5	*0.2*
601–700	25.7	*0.3*
701–800	25.5	*0.3*
801–860	25.6	*0.6*
	Quiet	
861–900	26.2	*0.5*
901–950	28.1	*0.4*
	Noise	
951–1010	26.6	*0.6*
1011–1060	24.9	*0.4*
	Quiet	
1061–1110	27.1	*0.4*
1111–1160	28.2	*0.4*

The first column gives the group of reactions of which the second column is the average. Each number represents the time for ten reactions. The P.E. is the median deviation divided by the square root of the number of cases.

keeps the subject on the alert, leaving no time for memorizing. It might be possible to fall into a rhythmic movement in reacting in task two, but not with task four. Hence we decided throughout the remainder of the experimenting to use task four. It had been planned to use all four tasks through the whole experiment, but we obtained little promise of finding any different effect with the different tasks we had chosen. They probably involved too nearly the same procedure to be affected differently.

II. *Experiments with Alternating Periods of Quiet and Noise*

In these experiments eight subjects were used, each subject for one sitting. Those marked A, B, C, and D in the table did not know that noises were to be introduced, while E, F, G, and H did.

D and H were women, all the rest were men subjects. B, C, D, E, F, and G were psychology students, B an undergraduate, the rest graduate students. A and G were not students. They worked about the university and had no experience in experimental psychology. H was the same subject who served in the work reported in Table I.

The procedure consisted in assigning to the subject the task described above as task four and introducing noises after he had worked for about half an hour in quiet. The noise period lasted about ten minutes and was followed by a quiet period. In some cases there were second noise periods given and in a few cases where time permitted the subject was given more than two noise periods.

The records for these experiments were calculated as before in groups of ten reactions. It was found that in every case there was little improvement in the first quiet period after the first half. In order therefore to put the results into comparable form each period, quiet and noisy, was divided into two equal parts, and the averages and probable errors calculated for each of these halves. They are given in Table III. A prolonged record was taken from subject H, and it is continued below the others. The figures below the times are the probable errors.

TABLE III

Speed Records in Alternating Quiet and Noisy Conditions

	Quiet		*Noisy*		*Quiet*		*Noisy*		*Quiet*	
A	61.8	62.9	61.6	57.8	63.2	58.5				
	1.8	*2.3*	*1.3*	*1.6*	*0.4*	*0.9*				
B	49.9	46.4	48.9	42.2	46.3	64.7				
	1.4	*0.6*	*0.5*	*0.6*	*4.2*	*3.9*				
C	47.7	43.4	50.0	45.5	45.5	40.5	44.5	40.5	38.5	42.3
	0.7	*0.7*	*0.3*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.2*	*0.1*
D	43.3	38.0	46.6	37.6	37.7	40.8	38.3	34.5	44.0	33.8
	0.6	*0.5*	*4.3*	*1.6*	*1.0*	*1.3*	*1.9*	*0.9*	*3.2*	*1.0*
E	32.0	28.2	26.5	25.6	26.2	28.1	26.6	24.9	27.1	28.2
	0.3	*0.3*	*0.3*	*0.3*	*0.5*	*0.4*	*0.6*	*0.4*	*0.4*	*0.4*
F	48.5	41.0	41.1	40.2	37.6	41.1				
	0.9	*0.8*	*1.8*	*1.2*	*1.7*	*2.0*				
G	45.7	40.4	39.0	35.8	35.5	38.3	36.3	34.7	38.5	37.0
	0.6	*0.5*	*0.5*	*0.2*	*0.3*	*1.3*	*0.7*	*1.1*	*0.9*	*1.4*
H	55.2	52.2	63.4	53.2	57.0	42.0	65.0	45.4	49.4	50.4
	0.4	*0.4*	*0.5*	*2.5*	*0.4*	*0.2*	*0.4*	*0.5*	*0.4*	*0.4*
H(continued)							53.0	48.0	50.0	40.4
							0.5	*0.4*	*0.5*	*0.4*

In five cases out of eight the first half of the first noise period shows a retardation in speed. Six out of the eight make better time in the second half of the first noise period than in the second half of the first quiet period. After the removal of the noise five show a slower reaction, one the same and two faster. A comparison of the second half of the second quiet period with the second half of the first noise period shows that with quiet six subjects make slower reactions than with the noises, while two make faster. In the beginning of the second noise period two make slower, three faster time than in the preceding quiet, while in the second half of this noise period the same three continue faster than in the preceding quiet. The last quiet period shows four subjects slower and one faster in both the first and second halves. The extension of H's record shows the same essential features with the exception that in the last score the best record is made.

In general, according to these eight subjects, the first introduction of the noises causes a retardation in time followed by an acceleration. The removal of the noise is likewise followed by a retardation which however is not succeeded by an acceleration as was the case in the noise period. The initial part of the second noise period does not show as much retardation as the first, nor is the retardation in the last quiet period as strong as that of the middle quiet period. We may state the facts briefly thus: Noise causes an initial slowing in speed followed by an increase, while the removal of the noises causes a retardation followed by normal.

In order to show more clearly the initial effect of the noise we have in Table IV presented the records for each of the eight subjects for forty reactions just before the noises were introduced and forty just after, in groups of ten reactions. The first part of the table

TABLE IV

Initial Effect of Noise

First Introduction

Subjects	Before Noise				During Noise			
A	58	62	76	66	65	61.5	71.5	62
B	43.5	44.5	45.5	44.5	57	58	44	44.5
C	43	36	40	48	53	46	47	44
D	37	35	40	38	56	45	39	34
E	29	26	25	27	31	26	26	26
F	38	40	36	36	55	43	40	33
G	37	36	41	46	48	39	40	39
H	52	52	55	50	64	62	51	53
Second Introduction								
C	45	41	39	41.5	45	44	41	40
D	36	46	37	44	45	34	36	37
E	28	27	28	30	30	25	26	28
G	39	41	35	36	36	38	35	32
H	62	52	40	44	64	42	48	44

represents the work at the beginning of the first noise period, and the second division the introduction of the second noise period.

In this detailed presentation it will be seen that seven out of the eight react more slowly in the first score after the first introduction of the noises, four out of eight more slowly in the second score, four out of eight in the third, while only one out of the eight reacts more slowly in the fourth score after the noises were presented. This shows how rapidly the first slowing effect of the noises is overcome. At the second introduction of the noises three make slower and two the same time on the first score, two slower and three faster the second score, one slower and four faster the third score, while four react faster and one the same in the fourth score. Here we see less of the initial shock than at the first introduction.

III. *Noise and Accuracy*

In scoring any test where there are a large number of errors, it is always a problem to know how to penalize, but in this experiment the errors are too few to be significant. The records shown in Table III comprise in all 5,155 reactions. In all this number there were only 172 errors, a percentage of 3.34. In Table V we give the percentage of errors for each subject in both quiet and noisy periods.

TABLE V

PERCENTAGE OF ERRORS IN QUIET AND NOISY PERIODS

Subject	Quiet	Noisy	Quiet minus Practice
A	2.69	1.17	2.22
B	3.87	3.97	3.80
C	1.11	1.66	0.00
D	4.85	7.50	6.13
E	5.40	1.70	6.52
F	5.00	1.00	4.28
G	1.70	2.19	1.71
H	3.70	4.62	3.53

In this table the figures under the caption "quiet" represent the percentage of errors made during the entire experiment when there were no noises. Those under "noisy" the percentage of errors made during the disturbance periods. The last column shows the percentages of errors in the quiet periods minus the practise portion of each subject's work. The practise portion deducted was obtained by making a graph of each subject's record and noting approximately where the curve struck a level. Eliminating the portion of the work preceding this point leaves the period in which the conditions were most favorable for accurate work in direct comparison with the noise period; which comparison nevertheless reveals no ill effect of the noises. In five cases this last column shows a slightly lower percentage of errors than the first, which means that a few more errors were made during the practise section than after the work was learned; but this difference is far from reliable.

The small number of errors also makes the differences decidedly equivocal, since two errors more or less on one side would throw the difference in the opposite direction. The nature of the errors likewise shows that they are not a serious factor. With the apparatus we used the least touch of a key made a record; consequently if the subject struck the edge of the key next to the one he meant to press, both keys recorded. The majority of the errors in the scores shown were of this nature. For these reasons we can conclude that the error records in this experiment are not significant one way or the other.

IV. *Conclusions Derived from this Chapter*

The results obtained from the experiments reported in this chapter show that:

1. When the disturbing noises were first introduced they caused a retardation in the speed of the work.
2. This slow period was followed by an acceleration, the subjects exceeding the speed they had made before the introduction of the disturbing noises.
3. After the removal of the disturbances the subjects again did slower work.
4. A similar retardation at the introduction of the disturbance followed by an acceleration, and a retardation after the removal of the noise is seen in other disturbance periods than the first.
5. The records of errors do not show any inferior grade of work during the disturbance. They are too few to be of any significance.

The question now arises: How shall we interpret these results? At first thought it may seem to follow that a noisy condition is more favorable than a quiet one. If six out of eight make better time during noise than before the noises were introduced, and if six out of eight make slower time after the noises stop, might it not follow that noises have a dynamogenic effect, spurring the subject to increased activity? This might be a legitimate conclusion were it not for the initial retardation at the beginning of the noise periods. If the influence were one of simple dynamogenesis, it does not seem plausible that the first effect should be one of interference. If a motor is going at a certain speed and more current is turned on it does not first stop or slow down and then take on speed and exceed its former motion, unless the direction of the increased current is reversed.

It is therefore not a legitimate interpretation of the data to ignore the slowing effect or pass over it lightly and say that in general the effect of noise is a stimulation; just as it would not be a proper treatment of the data to average the whole period together and conclude that the noise had no effect.

After giving each feature of the results due weight we do not conclude that a noisy condition is just as conducive to good work as a quiet one. Our work thus far has simply served to show that noises have *some* effect upon work, and that the effect is a complex one. In the following chapters we shall report some work in which we have endeavored to analyze this complex.

CHAPTER IV

REACTION TO NOISE AS SHOWN BY BREATHING

A SURVEY[1] of the experimental work that has been done in an attempt to discover the relation, if any, between breathing and cerebral processes would tend to make one wary of a problem requiring so great an expenditure of time and patience, and so devoid of anything definite in the way of results. While it may seem almost self-evident that attention and the different emotions have some effect upon breathing, when subjected to experimental control, results of the most diverse sort have been obtained. Most of the work that has been done—the work in which there has been so little agreement—has been concerned with the rate of breathing. Recently several investigations have been reported which claim success along another line, namely, the manner of breathing regardless of the rate. Stevens,[2] while in his review of the literature finding only contradiction in reference to changes in the *rate* of breathing, concludes from his experiment that there is a constant relation between attention and *depth* of respiration.

Still more recently Benussi[3] declares that he has found an invariable relation between the ratio of the length of inspirations and expirations, and the truthfulness or falseness of a subject's replies to questions. His method was to record about six respirations, have the subject answer questions either truthfully or falsely, and then record six more respirations. He then measured the time taken for each inspiration and each expiration and found the ratio between them. He found that the relation between the ratio before and after truth telling was always different from that before and after lying.

While it must be shown by future work whether the condition he finds is peculiar to lying or not, the method of treating the breathing seems a promising one. It may be that a quantitative study of the manner of breathing will in the future be productive of more fruitful results than the study of breathing rates has been. At any rate we were curious to see what effect such an experiment as the present one would have on the breathing of the subject, and decided to use a method somewhat akin to Benussi's in treating the data.

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[1] For such a survey see: Stevens, H. C., "A Plethysmographic Study of Attention," *Amer. Jour. of Psychol.*, 1905, *16*, 409–483.

[2] *Ibid.*

[3] Benussi, V., "Die Atmungssymptome der Lüge," *Archiv f. d. gesamte Psychol.*, 1914, *31*, 244–273.

Two subjects were first used, one (I) knew what to expect in the way of noises and one (*J*) knew nothing of the nature of the experiment. The same procedure was followed as in the previous experiments, with the exception that a graphic record was taken of the breathing of the subject through the entire experiment. The disturbances were the same series of noises. The time for each inspiration and each expiration was then measured and the ratio found between them, dividing the expiration by the inspiration. The results of these two subjects with the probable errors are given in Table VI.

TABLE VI

BREATHING RATIOS OF TWO SUBJECTS

Subject	Before	Quiet			Noise		Quiet		Noise		Quiet		
I	1.89	2.42	3.17	1.95	2.05	02.00	1.77	1.78	1.98	2.13	1.49	1.51	Ave.
	0.04	*0.16*	*0.16*	*0.10*	*0.09*	*0.06*	*0.06*	*0.04*	*0.10*	*0.05*	*0.03*	*0.04*	P.E.
J	1.41	3.50	6.13	5.90	7.49	10.06	5.38	4.47	13.83	10.62	6.03	5.47	Ave.
	0.15	*0.15*	*0.23*	*0.38*	*1.04*	*1.76*	*1.18*	*0.52*	*1.18*	*1.00*	*1.54*	*0.72*	P.E.

In the case of subject I, the ratio before work was 1.89. As soon as the work was begun it rose to 2.42, after which it kept increasing until in the middle of the first quiet period it reached 3.17. It then dropped to about normal. As soon as the noises were introduced it rose again, and dropped once more in the following quiet. The same thing occurred at the second introduction of the noises. With subject J the difference was much more striking, the ratio being radically different as soon as the subject began to work from what it was before he began, and being also changed greatly by the introduction of noises. The explanation of this change in breathing did not become apparent until we tried other subjects. The next subject (K) began to speak aloud as soon as the noises began and continued to do so all through the disturbance period, his ratio changing the same as the other subjects. This gave the clue as to the change in ratio and arrangements were then made to watch the subjects, they of course not knowing they could be seen. The next subject, L, did not speak at all and his ratio shows little difference. M about the middle of the first quiet period moved his lips as he did the work, and when the noises came he first closed them for some time and then began to speak the letters aloud. In Fig. 4 are seen some typical curves, showing more or less change due to articulation. It can be seen that the type of curve changes, the inspiration becoming short, while the expiration be-

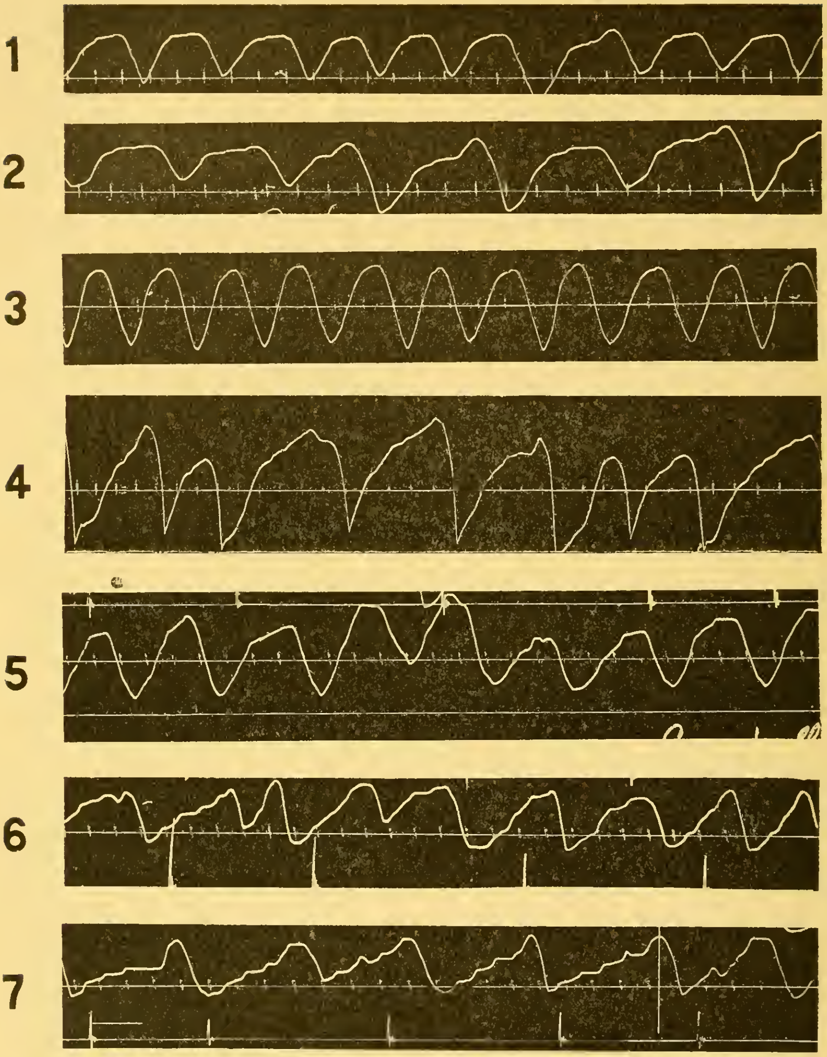

Fig. 4. Samples of breathing curves showing the changes caused by articulation. The curves read from left to right, and inspiration is recorded by a descent of the line, expiration by an ascent. The time line records intervals of a second.

1. Breathing curve of subject N while working in quiet.
2. Breathing curve of subject N while working in noise.
3. Breathing curve of subject T while working in quiet.
4. Breathing curve of subject T while working in noise.
5. Breathing curve of subject Br before he began to work.
6. Breathing curve of subject Br while working in quiet.
7. Breathing curve of subject Br while working in noise.

All of these subjects articulated during the noisy periods and subject Br during the quiet period as well. A comparison of 7 with 6 shows the increase in articulation of a subject who made vocimotor movements throughout the work.

The lines at the bottom of 6 and 7 are the records of the key pressure apparatus.

comes much lengthened. From these as well as later experiments where the subjects were watched it is certain that the extreme changes in ratio were due to the subject moving to a greater or less degree the organs of articulation as an aid in his reactions.

This throws important light on the nature of a subject's response to a noisy situation. It will be remembered that the task to be performed consisted in looking at the exposure opening where one of ten letters from the latter end of the alphabet was exposed on a colored background. The subject then had to look below the opening at a code and translate the letter to one of ten letters from the beginning of the alphabet. Then he had to look up above the exposure opening to one of three codes whose color corresponded to the one at the opening and then translate the letter to one of ten numbers, after which he pressed the corresponding key. Each pressure of the key brought a new letter and color to view and the subject repeated the process. Some subjects as soon as they began work articulated noticeably and continued to do so through the entire experiment, emphasizing the movements during the disturbances. Some did not do so noticeably until the disturbances came. The positive evidence that the more radical changes in the breathing ratio corresponded to the more extensive articulation and the weaker ones to lesser movements of the lips points to a relation between still smaller changes in ratio and weaker involuntary movements of the speech organs. If this can be shown to be the case by further investigations it may throw light on the work of Benussi and other work concerned with breathing and mental processes.

In order to see to what extent the subjects called in this aid to overcome the disturbance of the noises, ten different subjects were used for one sitting each. Only one of these subjects (*Q*) knew the nature of the problem. The same group of nine noises were used as disturbances. The procedure consisted in allowing each subject to make 400 reactions in quiet, the noises then being introduced and kept constantly sounding (changing from one to the other irregularly) for 200 reactions. The sitting closed with 200 reactions in quiet, making 800 reactions for each subject. Time and accuracy records were taken as well as continuous breathing records. The breathing ratios for these ten subjects are given in Table VII.

The averages given are for each hundred reactions with the exception that the first hundred reactions of the disturbance period are given in two groups of fifty each. Under each ratio is the probable error for that group.[4]

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[4] In order to economize time a change was made in the method of tabulating. Instead of measuring each inspiration and expiration separately, each group to be treated was divided into four approximately equal sections. The total time

TABLE VII

Breathing Ratios of Ten Subjects

		Quiet				Noise			Quiet	
	Before	1–100	101–200	301–300	301–400	401–450	451–500	501–600	601–700	701–800
K	1.84	2.04	2.22	3.04	3.13	5.14	4.42	4.67	3.56	3.08
		0.15	*0.13*	*0.40*	*0.13*	*0.02*	*0.26*	*0.46*	*0.26*	*0.25*
L	1.56	1.59	1.82	1.87	2.14	1.36	1.41	1.66	1.97	1.87
		0.09	*0.04*	*0.05*	*0.03*	*0.09*	*0.02*	*0.16*	*0.01*	*0.10*
M	1.43	1.56	1.95	3.15	2.88	1.44	4.92	4.33	2.48	2.08
		0.04	*0.18*	*0.37*	*0.04*	*0.07*	*0.92*	*0.57*	*0.10*	*0.09*
N	2.21	2.15	2.57	2.41	2.09	2.39	2.75	2.78	2.29	2.20
		0.13	*0.02*	*0.02*	*0.09*	*0.07*	*0.07*	*0.10*	*0.05*	*0.01*
O	1.14	1.55	1.52	1.50	1.51	1.62	1.85	1.68	1.52	1.71
		0.07	*0.04*	*0.10*	*0.15*	*0.02*	*0.09*	*0.05*	*0.03*	*0.07*
P	1.84	1.33	1.25	1.24	1.25	1.49	1.64	1.13	1.24	1.27
		0.05	*0.03*	*0.09*	*0.05*	*0.06*	*0.07*	*0.05*	*0.05*	*0.06*
Q	1.26	1.97	2.36	2.58	2.55	2.26	2.94	3.40	2.36	2.31
		0.11	*0.14*	*0.11*	*0.25*	*0.68*	*0.45*	*0.24*	*0.13*	*0.22*
R	1.32	1.72	1.86	2.28	2.24	1.35	1.48	1.70	1.97	1.40
		0.04	*0.05*	*0.06*	*0.09*	*0.04*	*0.07*	*0.05*	*0.15*	*0.08*
S	1.19	1.53	1.86	1.62	1.57	1.26	1.41	1.49	1.42	1.35
		0.07	*0.03*	*0.04*	*0.16*	*0.04*	*0.03*	*0.04*	*0.09*	*0.09*
T	1.45	1.41	2.25	1.96	1.62	1.35	2.46	3.42	1.70	2.14
		0.07	*0.09*	*0.08*	*0.05*	*0.13*	*0.31*	*0.18*	*0.07*	*0.07*
Ave.	1.53	1.68	1.97	2.17	2.10	1.97	2.53	2.63	2.05	1.94
Av. of P.E.		*0.08*	*0.08*	*0.13*	*0.10*	*0.12*	*0.22*	*0.19*	*0.09*	*0.10*

Nine of the ten subjects show a larger ratio during work than in the period before work. Seven of the ten show a larger ratio

for inspirations and expirations was found for each section and the ratio calculated from this. The probable error for each group is of four sections. This method, unless the distribution is much skewed, will not change the results. Several groups, selected at random from different subjects, were calculated in both ways in order to see if the difference was significant.

Measuring each reaction separately	Av.	1.89	1.55	1.96	3.03
	P.E.	*0.04*	*0.02*	*0.09*	*0.28*
Measuring by groups of four	Av.	1.90	1.53	1.94	2.99
	P.E.	*0.07*	*0.04*	*0.18*	*0.37*

The figures show that the averages are changed very little. The probable errors in the case of the more tedious method are smaller. The reason for this is that the groups of consecutive respirations differ more than would be expected from random samplings, while the cases within the same group differ less.

during the disturbance than during quiet. This shows quite a general tendency to articulate during the work as well as a tendency to use this as a help to overcome the disturbing noises. All of those who evidently used articulation as a help during the noises show a decrease in ratio after the noises stop. The averages of all subjects for each period show a tendency of the ratio to rise to a fairly high point during the quiet period, reaching its maximum at the 201–300 group and then to fall somewhat. At the first introduction of the noises the ratio is still lower, after which it rises to a higher point than it has yet reached. After the noises stop it again falls. It is evident that when the noises begin the subjects are somewhat confused and work ahead blindly and make slower time than they did during the quiet. After the first fifty reactions or so they begin to realize that they are in a situation not conducive to good or rapid work and then strike about for a means to overcome it. Those who discover the help of articulation overcome the slowing effect of the noises and make better time than they did during the quiet. (See Table IX.) That this effect in the averages of ratios is not produced by a few cases is shown in Table VIII where for each subject the different periods are given a ranking from 1 to 9 (omitting the period before work) from the lowest ratio to the highest. The periods were arranged according to their relative positions regardless of amount of difference, thus eliminating all chances of one or two excessive scores controlling the averages.

TABLE VIII

RELATIVE RANKING OF RATIO SCORES FOR EACH SUBJECT

	Quiet				Noise			Quiet	
Subject	1–100	101–200	201–300	301–400	401–450	451–500	501–600	601–700	701–800
K	1	2	3	5	9	7	8	6	4
L	3	5	6.5	9	1	2	4	8	6.5
M	2	3	7	6	1	9	8	5	4
N	2	7	6	1	5	8	9	4	3
O	5	3.5	1	2	6	9	7	3.5	8
P	7	4.5	2.5	4.5	8	9	1	2.5	6
Q	1	5	7	6	2	8	9	4	3
R	5	6	9	8	1	3	4	7	2
S	6	9	8	7	1	3	5	4	2
T	2	7	5	3	1	8	9	4	6
Av.	3.4	5.2	5.5	5.15	3.5	6.6	6.4	4.8	4.45
A.D.	*1.8*	*1.5*	*2.5*	*2.3*	*2.9*	*2.4*	*2.2*	*1.3*	*1.6*

Treating the scores in this manner gives the same result. The averages of orders gives in the first group the position 3.4, the next two 5.2 and 5.5 after which at the close of the quiet period it drops to position 5.15. At the introduction of the noises the average position is as low as 3.5. It then rises to 6.6 and 6.4. After the noises cease it drops again to 4.8 and 4.45.

Thus far we have considered the general tendency of the group. Let us look now more closely at those cases that do not follow this tendency. Their status can be seen by comparing the breathing ratios of Table VII with the time scores given in Table IX. Here it will be seen that there are some exceptions to the rule we previously found that subjects do as good or better work during noise than in quiet. The most striking exceptions are the subjects R, and S. These, who do not make better time during the noises, are the ones who do not show a lengthening in breathing ratios. Besides P, N, and O show longer times during at least part of the noise period, and likewise show little increase in breathing ratio. It is certainly evident that those subjects who excel in speed during the disturbances call in the aid of articulation as a means of overcoming the disturbances. The only clear exception is L, who made shorter time and who also shows no lengthening in breathing ratio. If the aid of articulation was the only factor by means of which the subject could modify his time score, we might expect a correlation between the time and breathing ratio scores; but, as will appear later, other factors are operative which cannot be expressed by correlations.

The breathing rates were also calculated for each subject through the entire periods and are given in Table X. The figure given is the average time per respiration. The figure beneath is the probable error for the group. The relative ranking is also given for each subject. While with some subjects a lengthening of the ratio was accompanied by a slower rate, with other subjects the action was just the opposite; and while the time averages as well as the relative position averages show somewhat the same effect, we could find no definite relation between the rate of breathing and articulation. A subject can change the length of ratio by articulation and at the same time either increase or decrease in rate. This shows that a statistical study of the manner of breathing gives information that would be made obscure and equivocal were the rates alone considered. Outside the fact that the breathing seems to be a little quicker at the beginning of work and at the beginning of the noise period, the breathing rate figures show little of anything definite. This quickening may, taken with the evidence from the other scores, be interpreted as an index of excitement at these two points in the experiment, but the lack of reliability of the rate scores taken alone is shown in the relative position scores. When there is little correspondence in ranking between the several individuals

TABLE IX

Time Scores of Ten Subjects

	Quiet				Noise			Quiet	
Subject	1–100	101–200	201–300	301–400	401–450	451–500	501–600	601–700	701–800
K	49.2	56.4	62.6	58.6	50.8	47.0	47.0	61.1	53.9
	1.4	*1.6*	*4.6*	*6.4*	*1.3*	*0.9*	*0.9*	*1.3*	*2.3*
L	46.2	42.0	38.6	38.3	42.6	37.0	36.1	39.7	40.6
	0.4	*0.6*	*0.5*	*0.7*	*2.2*	*0.9*	*0.9*	*0.8*	*6.3*
M	65.6	58.1	58.6	57.3	74.2	49.7	55.8	58.2	66.1
	0.8	*2.5*	*2.4*	*0.7*	*9.9*	*2.0*	*1.6*	*3.5*	*2.1*
N	51.7	47.7	44.8	46.0	53.6	38.3	46.4	41.5	45.0
	1.0	*1.3*	*1.6*	*0.6*	*3.4*	*1.4*	*2.0*	*1.4*	*1.7*
O	47.5	46.0	41.5	39.8	38.8	41.8	40.2	39.2	37.8
	1.0	*0.8*	*1.0*	*0.9*	*0.5*	*1.0*	*0.5*	*1.0*	*0.5*
P	45.0	40.2	36.2	36.1	48.0	42.0	38.1	35.9	35.2
	1.4	*1.1*	*0.6*	*0.7*	*2.7*	*2.7*	*2.2*	*0.5*	*0.6*
Q	49.0	44.8	41.5	40.1	47.8	36.4	34.9	36.2	33.7
	1.3	*1.0*	*1.1*	*1.4*	*1.4*	*1.2*	*1.3*	*0.8*	*2.4*
R	52.5	47.8	42.1	41.5	46.0	41.6	42.1	43.0	41.2
	1.1	*1.0*	*0.4*	*0.5*	*1.8*	*0.3*	*0.4*	*0.6*	*0.6*
S	45.6	42.0	35.9	35.7	39.4	37.6	36.3	37.5	35.4
	0.6	*1.1*	*0.6*	*0.7*	*2.0*	*1.6*	*0.5*	*0.5*	*0.8*
T	63.7	50.8	56.1	51.3	46.4	44.0	43.7	50.3	47.6
	1.1	*2.2*	*2.2*	*2.4*	*2.2*	*1.3*	*1.3*	*1.3*	*1.6*
Av.	51.6	47.6	45.8	44.5	48.8	41.5	42.1	44.3	43.6
Av. of P.E.s	*1.0*	*1.3*	*1.5*	*1.5*	*2.7*	*1.3*	*1.2*	*1.2*	*1.9*

Relative Ranking of Time Scores

K	3	6	9	7	4	1.5	1.5	8	5
L	9	7	4	3	8	2	1	5	6
M	7	4	6	3	9	1	2	5	8
N	8	7	3	5	9	1	6	2	4
O	9	8	6	4	2	7	5	3	1
P	8	6	4	3	9	7	5	2	1
Q	9	7	6	5	8	4	2	3	1
R	9	8	4.5	2	7	3	4.5	6	1
S	9	8	3	2	7	6	4	5	1
T	9	6	8	7	3	2	1	5	4
Av.	8.0	6.7	5.4	4.1	6.6	3.8	3.2	4.0	3.2
A.D.	*0.8*	*1.0*	*1.6*	*1.5*	*2.2*	*1.0*	*1.7*	*1.0*	*3.8*

of the experiment, their averages tend to bring them all together. The fact that the difference between the lowest and highest ranking is only 3.2 positions out of a possible 9 is indicative of a lack of correspondence between the individuals as to changes in breathing rate.

TABLE X

BREATHING RATES OF TEN SUBJECTS

		Quiet				Noise			Quiet	
Subject	Before	1–100	101–200	201–300	301–400	401–450	451–500	501–600	601–700	701–800
K	5.09	3.44	4.03	4.00	3.84	4.12	4.07	3.84	4.19	3.95
		0.20	*0.15*	*0.12*	*0.07*	*0.01*	*0.15*	*0.16*	*0.12*	*0.24*
L	3.94	2.80	2.77	2.85	2.75	2.10	2.27	2.89	3.23	2.83
		0.08	*0.07*	*0.03*	*0.02*	*0.02*	*0.07*	*0.06*	*0.05*	*0.05*
M	2.92	2.37	2.50	3.70	3.56	2.50	4.87	5.33	3.64	3.76
		0.05	*0.27*	*0.08*	*0.13*	*0.18*	*1.04*	*0.14*	*0.06*	*0.05*
N	4.25	2.69	3.07	2.98	3.19	3.07	3.42	3.56	3.03	3.20
		0.15	*0.09*	*0.04*	*0.11*	*0.07*	*0.14*	*0.05*	*0.06*	*0.09*
O	3.60	3.20	3.47	3.52	3.38	2.20	2.84	2.67	3.33	3.07
		0.11	*0.24*	*0.21*	*0.16*	*0.14*	*0.07*	*0.06*	*0.03*	*0.15*
P	3.71	2.90	3.12	3.26	3.22	3.10	3.39	3.04	3.49	3.42
		0.06	*0.05*	*0.06*	*0.09*	*0.02*	*0.25*	*0.03*	*0.06*	*0.13*
Q	3.35	2.65	3.32	3.02	3.54	3.24	3.46	3.26	3.02	2.78
		0.18	*0.49*	*0.05*	*0.17*	*0.12*	*0.05*	*0.04*	*0.21*	*0.16*
R	3.06	2.98	2.78	2.99	2.86	3.00	2.93	2.76	3.18	2.94
		0.06	*0.06*	*0.08*	*0.12*	*0.04*	*0.06*	*0.05*	*0.06*	*0.05*
S	2.85	2.72	2.98	2.84	2.71	2.15	2.35	2.35	2.66	2.47
		0.09	*0.05*	*0.09*	*0.03*	*0.09*	*0.04*	*0.07*	*0.14*	*0.09*
T	2.63	2.62	3.76	3.51	2.88	2.58	3.70	4.63	3.10	3.24
		0.06	*0.13*	*0.10*	*0.02*	*0.20*	*0.30*	*0.10*	*0.11*	*0.04*
Av.	3.54	2.84	3.18	3.27	3.19	2.11	3.33	3.43	3.29	3.17
Av. of P.E.s		*0.10*	*0.16*	*0.09*	*0.09*	*0.09*	*0.22*	*0.08*	*0.09*	*0.11*

RELATIVE RANKING OF RATE SCORES

K	1	6	5	2.5	8	7	2.5	9	4
L	5	4	7	3	1	2	8	9	6
M	1	2.5	6	4	2.5	8	9	5	7
N	1	4.5	2	6	4.5	8	9	3	7
O	5	8	9	7	1	3	2	6	4
P	1	4	6	5	3	7	2	9	8
Q	1	7	3.5	9	5	8	6	3.5	2
R	6	2	7	3	8	4	1	9	5
S	7	9	8	6	1	2.5	2.5	5	4
T	2	8	6	3	1	7	9	4	5
Av.	3.0	5.5	5.95	4.85	3.5	5.65	5.1	6.25	5.2
A.D.	*2.2*	*2.1*	*1.5*	*1.7*	*2.3*	*2.2*	*3.1*	*2.2*	*1.5*

SUMMARY OF CHAPTER

1. It was found that movements of the speech organs caused a change in the breathing. These changes corresponded in a general way to the extent of the movements; speaking aloud caused greater changes than whispering and simple movements of the lips lesser changes than whispering.

2. The ratio between the inspiration and expiration time expresses this change numerically.

3. The general tendency was for subjects to make movements of their speech organs as they performed the task.

4. There was likewise a general tendency to increase these movements as they worked in the midst of noises. This is shown by the increase in the breathing ratio.

5. Those subjects who called to their assistance this means of overcoming the effect of the noises increased in speed during the noises, and those who did not showed no such increase. There was only one exception to this.

6. This aid was not called forth at the very beginning of the noise period. It probably takes some time for the subject to awaken to the nature of the situation. The low breathing ratios at the beginning of the noise periods correspond closely to the slowing in time noted in the last chapter. When he realizes that he is being disturbed the subject begins to articulate, his breathing ratio increases and his time decreases.

CHAPTER V

COMPARISON OF QUIET AND NOISY PERIODS WITH RESPECT TO EFFORT

At the same time that we were experimenting with the breathing, it was desired to get some test which would indicate whether the subject was working at a greater tension while the noises were going on than when it was quiet. Several devices were tried in an effort to get a record of the involuntary movements of the subject while at work. The first two devices tried were not satisfactory for this experiment. One was to have the subject hold a rubber bulb in his left hand, any changes in pressure on this bulb making a record on a kymograph. We found, as did Geissler,[1] that it was allowed to rest lightly in the hand and most of the time gave only a straight line for a record. We then devised a dynamometer that required a certain strain on the part of the subject or it would fly out of his grasp. This however served as a greater disturbance than the noises. The subject would stop work entirely in order to readjust his hold and seemed more interested in holding it properly than in reacting, which of course made the record useless for our purpose.

We then tried to get a test that could be obtained without the subject being aware of it. A good one seemed that of taking a record of the amount of pressure exerted on the keys in the reactions, as such a test would have to receive some response from the subject, for he was forced to press the keys in order to react. It had the advantage of being directly related to the work in hand; hence a change in response would certainly be indicative of a change in his manner of reacting in the main task, which would facilitate interpretation of the results. If it could be obtained without the knowledge of the subject it would have the additional advantage of being free from voluntary modification by him.

As was stated in Chapter II in the description of the device used to record the pressure exerted on the keys, the apparatus that we adopted met this last condition to an unlooked-for degree. None of the subjects knew that his record was being taken till the experiment was concluded. For this reason we regard the results from this test as highly reliable. We have seen from the results of the time scores that when a subject knows a certain test is being made he does his best to make that score good. If his time is being taken and noises are sounded, he does his best and tries to show that he is not affected by the noises. Now such a reaction may be all right when individuals or groups are to be compared, but when the effect of some condition is to be studied such a response is disastrous. It covers the effect of the condition, and the experimenter is forced to conclude that he finds no effect of such a condition on the process tested; when as a matter of fact it had an effect but was hidden by the change in the subject's response. Let us see then if the results obtained in the previous chapters will have to receive a different interpretation in the light of this test of which the subject was in total ignorance.

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[1] Geissler, L. R., "The Measurement of Attention," *Amer. Jour. of Psychol.*, 1909, *20*, 509.

Key pressure records were obtained from the last six subjects reported on in the last chapter, in connection with the breathing records. For these six subjects as well as all those that will be reported later we took simultaneous time, accuracy, breathing, and key pressure records. The keys were carefully tested, and a scale constructed with a unit of fifty grams to correspond to the movement of the recording stylus in response to that pressure. Each key pressure record was measured by this scale and the measures grouped into hundreds to correspond to the other records; with the exception that the first hundred reactions of the noise period were divided into two groups of fifty. The average pressure in grams for each group was found with its probable error and appears in Table XI.

The figures in the lower table represent the relative ranking of each group from the lowest pressure to the greatest for each subject. In every case the keys were pressed with greater force during the noisy period than during the quiet. The probable errors show that this difference is reliable in every case. As a rule the subjects tended to use greater force in pressing the keys at the beginning of the experiment than they did after they became accustomed to the work. When noises are introduced they press with as great or greater force than at the beginning of the experiment. It does not drop again to a low pressure until the noises stop, when it falls to a lower point than it had reached before the noises came.

The force with which the keys are struck varies greatly with different subjects, covering a range from 100 to 1120 grams; which is probably due to the difference in the manner of touching the keys. Some subjects give a slow pressure, and these subjects as a rule record a light pressure. Others give the keys a quick and comparatively hard blow, which of course would give the recording stylus a greater movement. In spite of the great variation in the manner of striking the keys, the change in pressure is in every case

TABLE XI

Key Pressure Records of Six Subjects

	Quiet				Noise			Quiet	
Subject	1–100	101–200	201–300	301–400	401–450	451–500	501–600	601–700	701–800
O	671	418	411	406	525	465	439	347	346
	13	*6*	*12*	*6*	*11*	*9*	*6*	*6*	*5*
P	316	204	118	130	252	285	287	126	101
	8	*4*	*3*	*4*	*9*	*11*	*5*	*3*	*3*
Q	293	197	150	115	300	302	235	180	165
	14	*7*	*4*	*4*	*8*	*8*	*5*	*4*	*3*
R	976	872	905	935	1120	985	1008	798	798
	10	*12*	*12*	*11*	*17*	*14*	*12*	*8*	*11*
S	165	168	171	137	162	170	175	110	100
	3	*4*	*4*	*3*	*6*	*5*	*4*	5	*4*
T	208	156	123	109	269	325	281	190	144
	9	*3*	*5*	*6*	*8*	*9*	*5*	*5*	*4*
Av.	438	336	313	305	438	422	404	292	276
Av. of P.E.s	*9*	*6*	*7*	*6*	*10*	*9*	*6*	*5*	*5*

Relative Ranking

O	9	5	4	3	8	7	6	2	1
P	9	5	2	4	6	7	8	3	1
Q	7	5	2	1	8	9	6	4	3
R	6	3	4	5	9	7	8	1.5	1.5
S	5	6	8	3	4	7	9	2	1
T	6	4	2	1	7	9	8	5	3
Av.	7.0	4.7	3.7	2.8	7.0	7.7	7.5	2.9	1.75
A.D.	*1.3*	*0.6*	*1.7*	*1.2*	*1.3*	*0.9*	*1.0*	*1.1*	*0.8*

significant. This measure gives every evidence of being indicative of the tension under which the subject works. We are not sure that this can be held to be true in comparing different subjects; for instance, we can not say for certain that R worked under a greater tension or strain than P. This might be the case, although it is more likely to be the peculiarity in the subject's manner of striking the keys, but in comparing different periods for the same subject, we believe difference in pressure does indicate the relative effort exerted. If a subject fell into the habit of giving the keys a quick hard blow and in normal conditions averaged 935 grams, and when a disturbance was introduced reached 1120 grams, this would certainly mean that the subject gave the keys a harder blow; and such an increase in force would be indicative of an increased nervous discharge into the reacting movement, which in turn would indicate that the subject was in a state of greater nervous tension than before the noises came.

When the subject first begins work he is in a comparatively high state of tension; he wants to make a high score and keys himself up to it. As he works for half an hour and becomes accustomed to the task, he tends to relax somewhat. When the noises come on he sees that he has an additional factor to cope with, strains himself to a greater degree to meet it, and, as we have seen in the last chapter, calls in some new factor to aid him, so that his score may not be affected by this new intruder, noise. Although he relaxes a little as the noises continue, he keeps himself in a comparative state of tension until the noises stop, when he relaxes and his pressure is weaker than at any time in the experiment.

In order to make vivid the fact that these different tests measure different things and are not simply a different check on the same think, the correlations between the different scores were calculated and are presented in Table XII. The correlations for each subject were kept separate, and are so given. The method used in calculating them was that of "Differences in Relative Positions or Ranks," the formulæ being

$$r = 2 \sin \left(\frac{\pi}{6} p \right)$$

and

$$p = 1 - \frac{\Sigma D^2}{\frac{n(n^2 - 1)}{6}};$$

in which r equals the Pearson coefficient of correlation; ΣD^2, the sum of the squares of the differences in rank; and n the number of cases.

TABLE XII

Correlation of Scores from Various Tests

Subject	Time and Breathing Ratio r	Time and Key Pressure r	Breathing Ratio and Breathing Rate r	Breathing Ratio and Key Pressure r
O	−.157	.58	−.804	.28
P	.466	.794	−.042	.28
Q	−.477	.292	.647	−.09
R	.052	.209	.01	−.43
S	.115	.261	.89	.42
T	−.547	−.677	.96	.292
Av.	−.091	.243	.277	.125

With two subjects the correlation between the breathing rate and breathing ratio is high, but with the others it varies as far as a high negative correlation. Between the time and breathing ratio and the time and key pressure tests there is practically no correlation. We can see then that each of these tests measures a different thing.

To have measured the subject's time and drawn our conclusions from it alone (the accuracy records were insignificant throughout) would have been to have told only a small part of the story. With the two additional tests we can see with what cost the subject makes better time during the latter part of the noise period. With some subjects this is accomplished with the aid of articulation, while all subjects are at a greater strain.

Although the results of these experiments are definite, it may be felt that the subjects were too few to make them conclusive. We therefore carried the experiment much further and give in the next chapter a report of a much more elaborate series. Here also the conditions are somewhat changed, so that any incidental factor which might have influenced the results heretofore is eliminated. The evidence for our conclusions will become doubly strong when we have presented these experiments.

If we look back at the breathing ratio records (Table VII) of the subjects whose key pressure records are reported in Table XI, we see that subjects R and S are exceptions to the general tendency to articulate during the noises. The time records (Table IX) of these two subjects show very little difference during the noises from that of the normal conditions, except for the initial slowing. If we had simply the time and breathing records we should have to conclude that these two subjects were not hindered by the noises. In the light of the key pressure tests, however, we can say that while they did as rapid work and show no evidence of speaking to help themselves against the noises they worked at a greater tension.

These results show that the test of which the subject was totally ignorant gave the best results. This indicates, we believe, what should be the nature of tests to determine the influence of conditions upon human activity; for it is impossible to vary conditions to any marked degree without the subject becoming conscious of it, and his recognition of an added difficulty leads him to extra exertion to overcome it.

It may be thought that if this is the case the introspective evidence of a trained subject would reveal it. To discover whether we could obtain the information in this way every subject was asked if he put forth greater effort to combat the noises, whether he found it more difficult to work during the time when the noises were in progress. Only two subjects (whose records will be given later) confessed that they were bothered by the noises. These two subjects made slower records all through the noise periods. All confessed that it took greater effort at the beginning of the noise period. From these statements we believe that the subject's judgment of the difficulty of a task and the amount of effort he is exerting is simply a judgment of the rapidity with which he works. The fact of the case is, that after the first period he was able by strain and speaking to go as fast or faster than before the noises, and because he worked as rapidly he did not think it required extra effort.

Nor do we believe from our results that a judgment of the pleasantness or unpleasantness of the task is a report based on the effort put forth. The two subjects referred to above who did slower work and confessed that they had to work harder, were the only ones who said that the test was unpleasant. While we made no attempt to get a scale of pleasantness we asked all the subjects how they liked it, or some similar question. They would invariably laugh and give answers such as these; "I enjoyed it," "That's a good one," "You put one over on me that time," "Fine," "Say, that's all right." It was regarded as a joke because they had no idea that noises were to be given. Other factors enter into reports of pleasantness or unpleasantness than the amount of effort required.

Theoretically it might be possible to devise a test of such intense difficulty that the subject would have to exert himself to the utmost each moment. A disturbing change in the situation would then be sure to be recorded as a slowing of response in the task. Such a test however is practically impossible. No subject works to the last notch. He may even think that he is doing so, but if something comes to call for more energy he finds he has a reserve force to fall back upon.

Since there is no test which taxes the subject to the last notch at every moment, and since resistance causes him to put forth more energy to combat it, and since introspective evidence does not record the true situation; no test will give the true effect of a situation upon a reagent unless some check is obtained as to the amount of effort exerted. Experiments may be made without such a check, and the experimenter may conclude that such and such a condition had no effect on a given task; but he cannot consistently go on and affirm that because such a task was not affected by the given condition, this condition is just as good for the performance of the task as other so-called normal conditions would be. If we have an engine running a certain piece of machinery at a certain speed when it is well oiled, and then instead of oil put sand on the bearings; the governor of the engine may see that it gets more steam and the speed remain unchanged, but we cannot conclude, because the speed is the same, that the sand is as good a lubricant as oil. If we measure the steam consumed, the pressure that the piston meets, or some such factor, we could tell. It is this error that has led a number of experimenters to decide that certain abnormal conditions are as conducive to efficient work as are normal conditions. If a factor is important it cannot be ignored simply because it involves difficulties.

Summary of Chapter

1. In a very unequivocal way it was found that the subjects struck the keys with greater force in a noisy than in a quiet situation.
2. This change in pressure is indicative of greater nervous tension at such times.
3. There is no strong correlation between the key pressure, breathing, and time scores; and this shows that they vary independently of each other and give records of different facts.
4. The value of the key pressure test lies in the fact that because the subject was not aware that it was being taken, it gave indications of changes in tension without the complication of variations due to voluntary effort to overcome the changes. It is also valuable in that it was connected directly with the task to be performed and was a real part of it.

CHAPTER VI

A Comparison of the Effects of Various Noises

The purpose of the experiment to be described in this chapter was to give the conclusions of the previous experiments a further test as well as to see if the measures there described could be used to distinguish the effects of different kinds of noise disturbances. The same noises were used and appear in the tables under the caption Bb. Besides this set, six graphophone records were played to each subject. The abbreviations used in the tables for these selections are as follows:

Am—concertina solo. ("Amoresque Waltz.")
Sh—ocarino solo. ("Swiss Shepherd.")
Li—humorous dialogue. ("Liars, or My Uncle's Farm.")
Mo—humorous monologue. ("How Mother Made the Soup.")
Ki—tenor solo. ("Killarney.")
Sa—bass solo. ("Sentinel Asleep.")

The task was the same as that described for the experiments in the preceding chapters. The procedure consisted in the subject making three hundred reactions under quiet conditions. The disturbances were then introduced and kept going continuously until all six of the records had been played and the set of noises administered.[1] (The noises were given for about the same length of time that it took to play a record.) After the entire gamut of disturbances had been traversed a second quiet period was given which lasted till the subject made one hundred reactions.

In order that no disturbance should have any advantage or disadvantage due to position, each subject received them in a different order. The order was chance and for each subject was as follows:

Subject	Disturbances						
Bl	Li	Bb	Ki	Am	Sa	Mo	Sh
Sp	Bb	Am	Mo	Li	Sh	Ki	Sa
Sa	Ki	Sa	Sh	Am	Li	Bb	Mo
Br	Am	Mo	Li	Sa	Bb	Ki	Sh
Bo	Sa	Sh	Bb	Li	Am	Ki	Mo
Ch	Mo	Li	Ki	Bb	Sa	Am	Sh
Cr	Sh	Ki	Mo	Am	Bb	Li	Sa
Re	Li	Am	Sh	Ki	Bb	Mo	Sa

---

[1] We distinguish noises and graphophone records although in the tables they are all together classed as noises.

Subject	Disturbances						
Pf	Bb	Sa	Li	Mo	Ki	Sh	Am
Me	Ki	Mo	Bb	Sh	Sa	Am	Li
Ca	Am	Li	Sa	Ki	Mo	Sh	Bb
De	Mo	Sa	Bb	Li	Sh	Am	Ki
Hi	Sh	Mo	Am	Sa	Ki	Bb	Li
Kr	Bb	Sh	Li	Mo	Am	Sa	Ki
Ta	Sa	Ki	Am	Sh	Mo	Li	Bb

Records were taken of time, accuracy, breathing, and pressure exerted upon the keys throughout the entire set of experiments. The errors for a number of subjects was computed and in every case they were too few to be significant. The time scores were calculated as before (p. 23). The figures in Table XIII represent the time for ten reactions. The number below the average is the probable error (median deviation divided by the square root of the number of cases). Table XV shows the key pressure records in grams, each with its probable error. Table XVII gives the ratio of the expirations divided by the inspirations for the same subjects. Table XIX gives the time required for each complete respiration in seconds. The probable errors for the breathing and key pressure records likewise represent the median deviations divided by the square root of the number of cases. The first column of figures in the breathing tables represent the scores before the subject began work. In all four of these tables, namely XIII, XV, XVII and XIX, three columns of figures are given for the first quiet period, each figure being the average for one hundred reactions. Then follow seven columns giving the averages for the noise periods, which are arranged according to the disturbance used and do not represent the actual temporal sequence in which they were given. The last two columns are the averages for the last quiet period, each figure representing the average for fifty reactions. The averages at the foot of the tables represent the averages for the column under which it is placed, and the probable errors at the foot are the averages of the probable errors of the column.

In order that the results that these tables embody may be a little clearer and that no one subject shall have undue weight in the averages, we have arranged the results according to their relative positions and present them in tables XIV, XVI, XVIII, and XX. There are twelve scores reported for each subject, and in these tables they are arranged according to size from one to twelve. For example table fourteen shows that subject Bl made her fastest time in the first half of the last quiet period, the next fastest in the second half of the last quiet period, the third with the noise Sh, the fourth with noise Am, two tied for the fifth place (the last third of the first quiet period and noise Li) and so were given 5.5, the seventh Mo, etc. The averages in these tables are the average relative rankings for each position. The first figure below the average is the average deviation and below that the probable error, found by the formula;

$$\frac{\text{A.D. } .8453}{\sqrt{n}} = \text{P. E.}$$

In figures, 5, 6, 7, and 8 we represent graphically these relative rankings, with the range of reliability represented as the space between the dotted lines. The height of the curves is the relative ranking and the positions along the base the scores in the order that they appear in the original score tables.

It can be seen from the figures and from the curves that in the practice or first quiet period the time and key pressure records decrease, the breathing rate and ratio rise slightly. During the disturbance Bb, which was the set of harsh noises, the times are longer, the keys are struck much harder, the breathing ratio is greatly lengthened, while the breathing rate shows no reliable change. This accords with the findings of our previous experiments and thus corroborates the conclusions brought out in the preceding chapters. To the time records with the different graphophone records we can give no certain interpretation. Whatever the cause, better time was made during the instrumental selections than during the humorous speeches and vocal solos, and a little better also than in the final quiet period. The key pressure records show that the keys were struck harder all through the disturbances than either before or after. The breathing ratios show a notable lengthening throughout the noise period as compared with the quiet periods. The two graphophone records that show the fastest time show the highest key pressure record, and one of the two, Sh, the highest breathing ratio. The record Sa with the slowest time has the lowest key pressure record and the lowest breathing ratio record.

These comparisons show that those disturbances during which the time is accelerated are accompanied by increased key pressure and lengthened breathing ratios. Those disturbances during which the time is slower show not so much increase in key pressure and not so much lengthening of breathing ratio.

The breathing ratios become more significant when we mention the fact that all the subjects in this experiment except the first four in the tables were told not to speak during the experiment. This was done in order to see whether the change in breathing occurred when the lip movements were restrained. While they are not so radical as changes where the subjects were left free they are never-

TABLE XIII

Time Scores with Varied Noises

	Quiet			*Noises*							*Quiet*	
Subjects				Bb	Am	Sh	Li	Mo	Ki	La		
Bl	53.2	49.3	45.0	47.3	43.6	39.2	45.0	45.6	54.0	48.0	36.4	38.2
	2.1	*1.3*	*1.0*	*1.8*	*2.1*	*1.0*	*4.0*	*0.9*	*4.0*	*4.0*	*1.5*	*1.0*
Sp	41.3	41.7	37.6	38.4	37.3	37.1	38.0	36.8	35.7	34.4	34.8	33.6
	0.5	*1.0*	*0.8*	*1.5*	*1.7*	*1.8*	*1.9*	*1.8*	*1.3*	*0.3*	*0.5*	*0.6*
Sa	51.7	48.0	44.3	51.0	40.8	41.4	43.3	45.5	47.3	45.2	46.2	45.0
	1.8	*1.5*	*1.1*	*2.0*	*1.3*	*0.7*	*1.2*	*1.5*	*1.3*	*2.4*	*1.4*	*2.5*
Br	66.3	61.5	59.4	48.8	65.3	53.3	52.5	56.7	55.3	51.6	48.8	48.0
	1.4	*1.1*	*1.3*	*1.9*	*3.9*	*3.1*	*2.5*	*0.9*	*3.1*	*0.8*	*1.7*	*2.5*
Bo	73.4	68.6	64.5	55.7	53.8	55.0	54.3	55.7	55.3	58.3	56.6	59.2
	1.4	*1.0*	*0.8*	*1.4*	*1.0*	*0.7*	*1.6*	*1.9*	*3.6*	*1.3*	*1.5*	*0.8*
Ch	52.0	48.0	47.0	39.5	40.7	42.5	41.7	42.5	43.3	44.0	42.8	40.8
	0.9	*0.7*	*1.1*	*0.3*	*1.2*	*0.3*	*0.7*	*0.8*	*0.8*	*2.9*	*3.3*	*0.8*
Cr	54.5	53.9	53.1	53.5	49.7	51.2	51.3	49.3	50.0	51.7	51.0	51.8
	1.3	*2.5*	*1.6*	*0.6*	*1.6*	*0.2*	*1.9*	*1.5*	*0.3*	*0.7*	*4.5*	*0.8*
Re	71.8	66.3	67.5	77.0	60.7	66.0	80.0	70.7	74.5	72.5	70.4	71.0
	1.3	*0.7*	*1.1*	*2.7*	*0.4*	*1.1*	*4.9*	*0.5*	*2.5*	*2.5*	*2.0*	*2.5*
Pf	63.7	63.8	54.5	68.6	50.2	52.0	55.3	51.7	58.6	68.3	53.4	52.0
	1.5	*0.2*	*1.3*	*8.7*	*3.3*	*4.5*	*5.0*	*3.1*	*4.8*	*4.6*	*2.4*	*3.6*
Me	45.6	42.1	41.4	37.2	38.0	38.8	37.5	41.0	42.0	36.0	38.5	36.2
	1.1	*0.8*	*1.0*	*1.4*	*0.5*	*0.9*	*1.8*	*0.3*	*1.0*	*1.0*	*0.6*	*0.5*
Ca	47.5	46.9	50.1	50.0	50.5	47.5	60.7	59.7	45.2	49.3	41.4	41.8
	1.0	*2.1*	*2.5*	*4.0*	*4.3*	*4.8*	*7.1*	*4.1*	*2.5*	*3.9*	*2.0*	*0.9*
De	42.4	38.2	37.1	38.2	35.5	36.3	36.0	38.4	39.5	39.5	37.8	39.3
	0.5	*0.6*	*0.7*	*1.6*	*0.6*	*0.8*	*0.9*	*0.6*	*1.3*	*1.0*	*1.0*	*1.8*
Hi	45.6	43.1	43.3	37.8	40.8	38.6	39.2	42.0	37.5	40.5	38.8	38.1
	1.1	*0.8*	*0.5*	*0.6*	*0.5*	*1.1*	*1.9*	*0.7*	*1.0*	*0.5*	*0.7*	*0.7*
Kr	54.7	45.7	42.9	37.4	38.2	37.7	39.2	36.4	36.3	40.5	39.8	40.8
	1.1	*1.1*	*1.7*	*1.5*	*0.8*	*1.9*	*1.1*	*1.6*	*0.7*	*1.3*	*1.3*	*1.7*
Ta	52.2	49.9	51.5	46.0	46.5	50.7	64.6	42.5	49.2	56.3	45.2	53.8
	0.8	*0.7*	*1.0*	*2.0*	*1.8*	*1.1*	*2.6*	*1.0*	*0.3*	*0.4*	*2.1*	*1.9*
Av.	54.4	51.2	49.2	48.2	46.0	45.8	49.2	47.5	48.1	49.1	45.4	45.9
Av. of P.E.s	*1.2*	*1.1*	*1.1*	*2.1*	*1.7*	*1.6*	*2.6*	*1.4*	*1.9*	*1.8*	*1.8*	*1.5*

TABLE XIV

RELATIVE RANKING OF TIME SCORES

Subjects	*Quiet*			*Noises*							*Quiet*	
				Bb	Am	Sh	Li	Mo	Ki	Sa		
Bl	11	10	5.5	8	4	3	5.5	7	12	9	1	2
Sp	11	12	8	10	7	6	9	5	4	2	3	1
Sa	12	10	4	11	1	2	3	7	9	6	8	5
Br	12	10	9	2	11	6	5	8	7	4	3	1
Bo	12	11	10	5.5	1	3	2	5.5	4	8	7	9
Ch	12	11	10	1	2	5.5	4	5.5	8	9	7	3
Cr	12	11	9	10	2	5	6	1	3	7	4	8
Re	8	3	4	11	1	2	12	6	10	9	5	7
Pf	9	10	6	12	1	3.5	7	2	8	11	5	3.5
Me	12	11	9	3	5	7	4	8	10	1	6	2
Ca	5.5	4	9	8	10	5.5	12	11	3	7	1	2
De	12	6.5	4	6.5	1	3	2	8	10.5	10.5	5	9
Hi	12	10	11	2	8	4	6	9	1	7	5	3
Kr	12	11	10	3	5	4	6	2	1	8	7	9
Ta	9	6	8	3	4	7	12	1	5	11	2	10
Av.	10.8	9.1	7.8	6.4	4.2	4.4	6.4	5.7	6.4	7.3	4.6	4.9
A.D.	*1.4*	*2.2*	*2.0*	*3.4*	*3.4*	*1.4*	*2.7*	*3.6*	*3.1*	*2.3*	*1.8*	*2.9*
P.E.$_{t-0}$	*.31*	*.48*	*.44*	*.74*	*.75*	*.33*	*.59*	*.78*	*.68*	*.50*	*.39*	*.65*

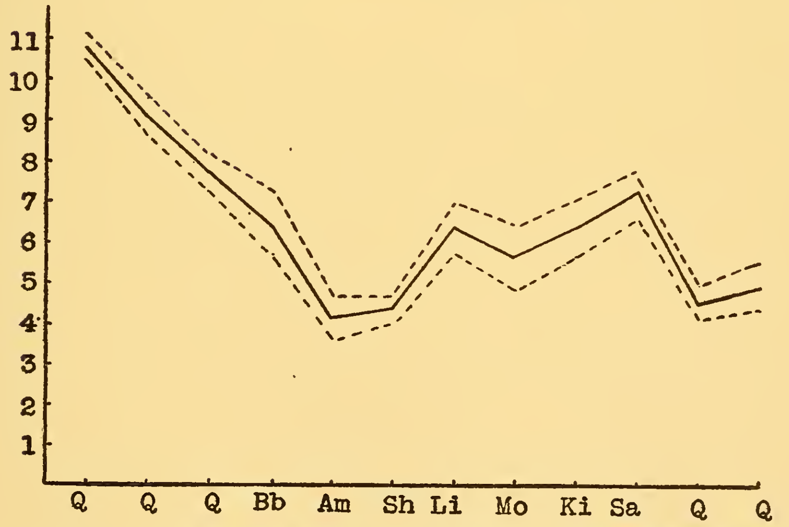

FIG. 5. Curve showing the relative ranking of the time scores. The probable errors are included within the dotted lines. The divisions along the base represent the quiet and noise periods. The order of the disturbances does not represent any time sequence.

TABLE XV

Key Pressure Scores with Varied Noises

	Quiet			*Noises*							*Quiet*	
Subjects				Bb	Am	Sh	Li	Mo	Ki	Sa		
Bl	380	240	250	330	280	250	270	250	342	313	220	210
	17	*4*	*3*	*3*	*7*	*2*	*5*	*3*	*3*	*4*	*4*	*5*
Sp	457	490	482	587	550	515	558	522	521	515	470	468
	3	*7*	*4*	*9*	*4*	*5*	*4*	*7*	*7*	*6*	*1*	*6*
Sa	580	585	565	407	560	610	540	350	620	590	290	265
	13	*8*	*8*	*5*	*10*	*5*	*10*	*5*	*10*	*14*	*10*	*6*
Br	570	442	333	444	423	393	358	375	355	351	338	304
	10	*7*	*10*	*10*	*9*	*20*	*10*	*9*	*6*	*17*	*12*	*12*
Bo	213	252	269	413	297	317	387	299	298	305	308	248
	3	*3*	*5*	*7*	*4*	*7*	*13*	*2*	*5*	*6*	*5*	*4*
Ch	450	233	141	368	195	162	139	205	166	196	158	144
	8	*7*	*4*	*15*	*5*	*6*	*6*	*12*	*8*	*14*	*5*	*10*
Cr	379	255	263	156	157	203	135	186	209	164	157	187
	5	*5*	*10*	*5*	*7*	*3*	*8*	*3*	*6*	*8*	*4*	*9*
Re	438	443	490	490	455	491	525	515	387	430	365	465
	9	*13*	*18*	*18*	*33*	*36*	*36*	*23*	*32*	*37*	*20*	*21*
Pf	712	730	640	765	630	595	565	628	587	585	605	620
	6	*6*	*7*	*8*	*10*	*6*	*12*	*9*	*14*	*15*	*10*	*9*
Me	1420	1525	1625	1605	1580	1625	1575	1605	1635	1640	1615	1454
	10	*6*	*5*	*5*	*14*	*8*	*15*	*6*	*8*	*7*	*8*	*22*
Ca	531	440	400	500	530	372	525	485	350	415	330	365
	11	*7*	*8*	*12*	*15*	*15*	*10*	*16*	*5*	*18*	*8*	*9*
De	190	150	150	205	195	195	205	190	185	180	155	175
	4	*3*	*4*	*5*	*4*	*5*	*6*	*4*	*5*	*5*	*4*	*4*
Hi	383	362	335	352	325	365	312	362	320	345	280	347
	1	*2*	*1*	*3*	*2*	*2*	*2*	*3*	*1*	*4*	*4*	*3*
Kr	325	275	260	358	315	340	345	315	300	280	197	260
	4	*3*	*5*	*3*	*6*	*4*	*5*	*6*	*7*	*7*	*7*	*5*
Ta	355	302	283	402	285	335	350	360	320	292	345	320
	3	*5*	*5*	*4*	*9*	*6*	*7*	*4*	*9*	*9*	*5*	*5*
Av.	492	448	432	492	452	450	452	442	439	440	388	384
Av. of Av. of P.E.s	*7*	*6*	*6*	*7*	*9*	*9*	*10*	*5*	*8*	*11*	*7*	*9*

TABLE XVI

Relative Ranking of Key Pressure Scores

	Quiet			*Noises*							*Quiet*	
Subjects				Bb	Am	Sh	Li	Mo	Ki	Sa		
Bl	12	3	5	10	8	5	7	5	11	9	2	1
Sp	1	5	4	12	10	6.5	11	9	8	6.5	3	2
Sa	8	9	7	4	6	11	5	3	12	10	2	1
Br	12	10	2	11	9	8	6	7	5	4	3	1
Bo	1	2	3	12	5	10	11	7	6	8	9	4
Ch	12	10	2	11	7	5	1	9	6	8	4	3
Cr	12	10	11	2	3.5	8	1	6	9	5	3.5	7
Re	4	5	8.5	8.5	6	10	12	11	2	3	1	7
Pf	10	11	9	12	8	4	1	7	3	2	5	6
Me	1	3	9.5	6.5	5	9.5	4	6.5	11	12	8	2
Ca	12	7	5	9	11	4	10	8	2	6	1	3
De	7.5	1.5	1.5	11	9.5	9.5	12	7.5	6	5	3	4
Hi	12	9.5	5	8	4	11	2	9.5	3	6	1	7
Kr	9	4	2.5	12	7.5	10	11	7.5	6	5	1	2.5
Ta	11	2	1	12	8	10	9	6	4	5	7	3
Av.	8.3	6.1	5.1	9.4	7.2	8.1	6.9	7.3	6.3	6.3	3.6	3.6
A.D.	*3.6*	*3.1*	*2.4*	*2.4*	*1.8*	*2.2*	*3.7*	*1.4*	*2.6*	*2.1*	*2.0*	*1.8*
P.E._{t-0}	*.79*	*.68*	*.53*	*.53*	*.40*	*.48*	*.82*	*.31*	*.57*	*.46*	*.44*	*.40*

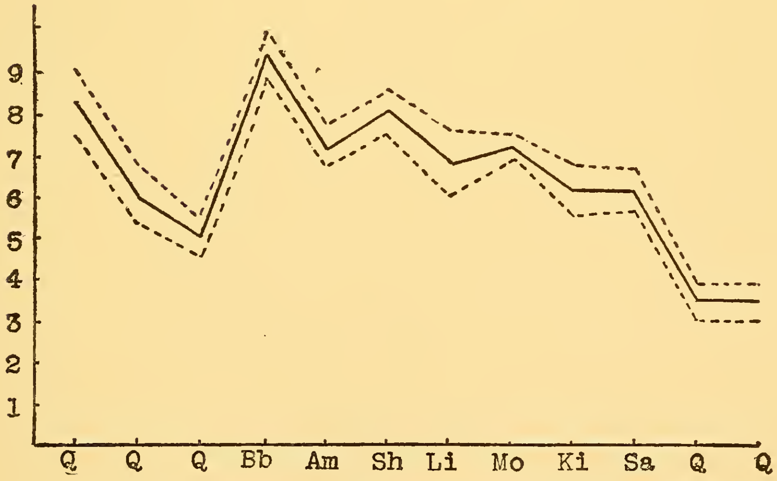

Fig. 6. Curve showing the relative ranking of the key pressure scores. The order of the disturbances does not represent any time sequence.

TABLE XVII

Breathing Ratio Scores with Varied Noises

	Before	*Quiet*			*Noises*							*Quiet*	
Subjects					Bb	Am	Sh	Li	Mo	Ki	Sa		
Bl	1.77	2.97	2.23	1.90	3.86	2.75	1.97	2.82	2.22	2.50	3.02	1.76	2.05
		.09	*.06*	*.05*	*.26*	*.05*	*.15*	*.15*	*.11*	*.12*	*.19*	*.05*	*.09*
Sp	1.50	1.53	1.51	1.62	1.98	2.17	2.16	2.22	1.95	2.14	2.03	2.00	1.96
		.05	*.02*	*.02*	*.09*	*.05*	*.05*	*.03*	*.04*	*.06*	*.12*	*.03*	*.03*
Sa	1.53	3.08	3.30	4.43	3.79	6.18	5.05	4.10	4.78	4.58	4.64	3.04	4.33
		.21	*.20*	*.20*	*.24*	*.54*	*.51*	*.14*	*.13*	*.45*	*.34*	*.11*	*.50*
Br	1.70	2.87	2.68	2.93	4.02	2.70	3.47	3.46	2.84	3.02	3.18	2.63	2.79
		.14	*.12*	*.09*	*.33*	*.05*	*.16*	*.18*	*.08*	*.11*	*.25*	*.30*	*.15*
Bo	2.28	1.86	1.97	2.83	2.74	3.24	3.43	2.96	2.93	2.70	2.99	2.74	2.65
		.05	*.06*	*.13*	*.06*	*.20*	*.07*	*.34*	*.18*	*.13*	*.14*	*.06*	*.08*
Ch	3.20	3.18	4.05	3.39	7.53	3.95	4.09	3.66	4.68	4.27	5.49	4.19	4.02
		.20	*.18*	*.11*	*.56*	*.30*	*.09*	*.29*	*.44*	*.12*	*.41*	*.28*	*.31*
Cr	2.37	2.61	2.33	2.52	3.24	3.40	3.35	3.27	3.34	3.47	2.82	2.63	2.45
		.07	*.12*	*.30*	*.19*	*.06*	*.14*	*.08*	*.16*	*.20*	*.14*	*.04*	*.03*
Re	1.21	2.43	2.77	3.40	3.40	3.40	4.24	3.90	3.98	4.91	3.80	3.28	3.50
		.21	*.12*	*.06*	*.22*	*.32*	*.51*	*.18*	*.44*	*.31*	*.52*	*.19*	*.19*
Pf	1.78	3.60	4.07	3.51	3.82	3.78	3.83	3.72	4.05	3.99	3.51	4.53	4.36
		.24	*.10*	*.08*	*.13*	*.13*	*.19*	*.26*	*.20*	*.09*	*.22*	*.24*	*.29*
Me	1.57	2.31	2.54	2.83	2.39	3.51	4.07	2.95	3.62	2.88	3.48	2.50	2.48
		.10	*.09*	*.14*	*.28*	*.12*	*.33*	*.44*	*.40*	*.19*	*.26*	*.02*	*.02*
Ca	2.28	1.81	1.96	1.97	2.40	1.96	2.51	2.33	3.75	2.41	2.43	2.21	1.98
		.03	*.03*	*.04*	*.24*	*.03*	*.10*	*.18*	*1.08*	*.12*	*.15*	*.09*	*.04*
De	1.74	1.93	1.70	1.86	2.20	2.14	2.29	2.30	2.45	2.55	1.83	2.03	1.76
		.10	*.05*	*.05*	*.05*	*.09*	*.11*	*.10*	*.09*	*.14*	*.07*	*.07*	*.01*
Hi	2.80	2.61	3.00	3.02	4.14	4.22	3.99	4.92	3.98	3.85	3.98	3.91	2.84
		.19	*.10*	*.12*	*.25*	*.13*	*.17*	*.14*	*.16*	*.28*	*.08*	*.05*	*.13*
Kr	1.73	1.84	2.04	2.13	1.91	2.03	2.08	2.10	1.95	2.84	2.29	2.16	2.44
		.04	*.03*	*.08*	*.06*	*.06*	*.06*	*.10*	*.06*	*.05*	*.12*	*.03*	*.06*
Ta	2.51	6.88	4.19	3.93	10.51	6.06	6.50	6.19	5.28	4.32	4.77	5.52	4.20
		.21	*.65*	*.46*	*.69*	*.62*	*.41*	*.35*	*.22*	*.20*	*.30*	*.13*	*.86*
Av.	2.00	2.77	2.67	2.81	3.86	3.43	3.31	3.34	3.46	3.33	3.33	3.01	2.92
Av. of P.E.s		*.13*	*.13*	*.13*	*.24*	*.18*	*.20*	*.20*	*.25*	*.17*	*.23*	*.11*	*.19*

TABLE XVIII

Relative Ranking of Breathing Ratio Scores

	Quiet			*Noises*							*Quiet*	
Subjects				Bb	Am	Sh	Li	Mo	Ki	Sa		
Bl	10	6	2	12	8	3	9	5	7	11	1	4
Sp	2	1	3	6	11	10	12	4	9	8	7	5
Sa	2	3	7	4	12	11	5	10	8	9	1	6
Br	6	2	7	12	3	11	10	5	8	9	1	4
Bo	1	2	7	5.5	11	12	9	8	4	10	5.5	3
Ch	1	6	2	12	4	7	3	10	9	11	8	5
Cr	4	1	3	7	11	10	8	9	12	6	5	2
Re	1	2	5	5	5	11	9	10	12	8	3	7
Pf	3	10	1.5	6	5	7	4	9	8	1.5	12	11
Me	1	5	6	2	10	12	8	11	7	9	4	3
Ca	1	2	4	8	3	11	7	12	9	10	6	5
De	5	1	4	8	7	9	10	11	12	3	6	2
Hi	1	3	4	10	11	9	12	7.5	5	7.5	6	2
Kr	1	5	8	2	4	6	7	3	12	10	9	11
Ta	11	2	1	12	8	10	9	6	4	5	7	3
Av.	3.3	3.4	4.3	7.4	7.5	9.3	8.1	8.0	8.4	7.9	5.4	4.8
A.D.	*2.6*	*2.0*	*1.9*	*2.9*	*2.9*	*1.9*	*2.0*	*2.4*	*2.2*	*2.2*	*2.3*	*2.1*
P.E.$_{t-0}$	*.57*	*.44*	*.41*	*.64*	*.64*	*.42*	*.43*	*.52*	*.47*	*.47*	*.50*	*.46*

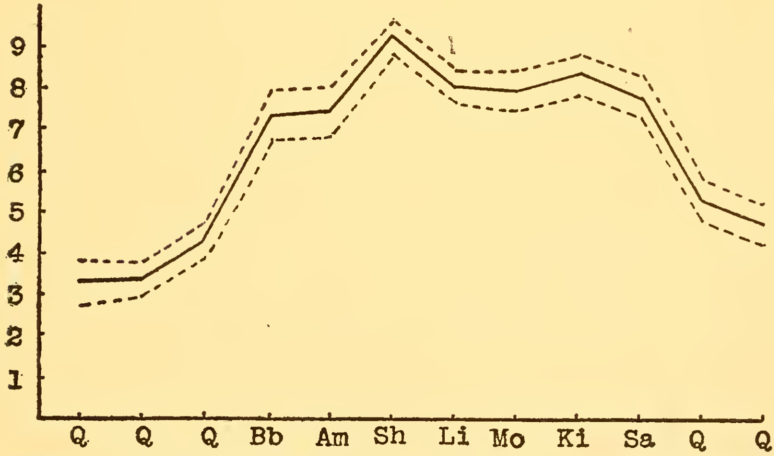

Fig. 7. Curve showing the relative ranking of the breathing ratio scores. The order of the disturbances does not represent any time sequence.

TABLE XIX

Breathing Rate Scores with Varied Noises

	Before	*Quiet*			*Noises*							*Quiet*	
Subjects					Bb	Am	Sh	Ll	Mo	Kl	Sa		
Bl	3.42	3.55	3.46	3.47	4.08	3.15	2.98	4.41	4.03	3.60	3.70	3.22	3.67
		.11	*.02*	*.02*	*.34*	*.04*	*.01*	*.30*	*.10*	*.12*	*.15*	*.05*	*.10*
Sp	2.43	2.43	2.70	2.68	2.64	2.71	2.86	2.95	2.88	2.83	2.85	2.85	2.71
		.05	*.05*	*.04*	*.04*	*.22*	*.04*	*.02*	*.04*	*.08*	*.06*	*.06*	*.09*
Sa	3.00	3.50	4.35	4.53	3.44	5.42	4.94	5.28	5.00	4.12	4.72	4.55	5.06
		.12	*.18*	*.14*	*.14*	*.13*	*.35*	*.41*	*.04*	*.21*	*.30*	*.05*	*.10*
Br	3.41	3.76	3.97	4.27	5.84	3.60	4.13	4.14	3.86	3.96	4.45	4.29	4.16
		.08	*.11*	*.13*	*.42*	*.23*	*.23*	*.08*	*.12*	*.18*	*.42*	*.07*	*.23*
Bo	3.35	3.01	3.28	3.59	3.72	3.75	3.61	3.40	3.63	3.60	3.36	3.63	3.46
		.04	*.04*	*.09*	*.14*	*.17*	*.03*	*.06*	*.06*	*.12*	*.14*	*.03*	*.07*
Ch	3.41	4.42	5.24	4.38	4.45	4.50	4.76	4.27	4.26	4.35	4.54	4.68	4.30
		.25	*.09*	*.10*	*.19*	*.18*	*.23*	*.19*	*.12*	*.15*	*.23*	*.06*	*.18*
Cr	3.63	2.93	3.19	3.36	2.80	3.12	2.78	2.89	3.00	2.91	2.91	3.33	3.70
		.09	*.03*	*.03*	*.08*	*.05*	*.05*	*.05*	*.09*	*.05*	*.05*	*.08*	*.15*
Re	3.15	3.42	3.18	3.20	2.93	3.30	3.30	3.10	3.10	3.23	3.19	3.95	4.04
		.16	*.10*	*.06*	*.08*	*.17*	*.07*	*.10*	*.14*	*.14*	*.18*	*.05*	*.13*
Pf	2.70	3.17	3.42	3.28	2.36	2.45	2.64	2.48	2.87	2.61	3.02	3.49	3.53
		.17	*.05*	*.05*	*.10*	*.07*	*.14*	*.20*	*.23*	*.04*	*.12*	*.10*	*.06*
Me	3.00	3.50	3.56	3.33	2.44	3.87	4.37	3.31	3.53	2.87	3.42	3.28	3.47
		.08	*.10*	*.05*	*.08*	*.25*	*.08*	*.09*	*.30*	*.14*	*.04*	*.03*	*.06*
Ca	3.60	3.36	3.47	3.53	3.39	3.44	3.23	3.95	5.15	3.44	3.34	3.50	3.41
		.02	*.06*	*.07*	*.08*	*.03*	*.04*	*.18*	*.91*	*.07*	*.04*	*.03*	*.05*
De	2.92	2.54	2.48	2.58	3.05	2.58	2.79	3.07	2.77	3.14	2.69	2.98	2.88
		.10	*.01*	*.01*	*.07*	*.09*	*.07*	*.11*	*.08*	*.10*	*.09*	*.05*	*.03*
Hi	2.90	3.33	3.13	3.47	5.66	4.98	4.78	6.80	5.61	4.68	4.58	5.80	3.54
		.24	*.02*	*.14*	*.54*	*.18*	*.20*	*.05*	*.08*	*.28*	*.25*	*.08*	*.13*
Kr	2.81	2.70	2.63	2.78	2.25	2.62	2.75	2.81	2.77	2.77	2.81	2.72	2.84
		.03	*.02*	*.04*	*.11*	*.05*	*.11*	*.04*	*.05*	*.07*	*.05*	*.02*	*.07*
Ta	3.54	3.64	3.46	3.49	3.88	3.77	3.87	3.64	3.78	4.39	3.29	4.03	3.85
		.13	*.14*	*.27*	*.39*	*.31*	*.10*	*.08*	*.16*	*.26*	*.24*	*.24*	*.50*
Av.	3.21	3.33	3.43	3.46	3.53	3.54	3.58	3.76	3.74	3.50	3.52	3.75	3.64
Av. of P.E.s		*.11*	*.07*	*.08*	*.19*	*.15*	*.12*	*.13*	*.17*	*.13*	*.16*	*.07*	*.13*

TABLE XX

Relative Ranking of Breathing Rate Scores

	Quiet			*Noises*							*Quiet*	
Subjects				Bb	Am	Sh	Li	Mo	Ki	Sa		
Bl	6	4	5	11	2	1	12	10	7	9	3	8
Sp	1	4	3	2	5.5	10	12	11	7	8.5	8.5	5.5
Sa	2	4	5	1	12	8	11	9	3	7	6	10
Br	6	2	7	12	3	11	10	5	8	9	1	4
Bo	1	2	6	11	12	8	4	9.5	7	3	9.5	5
Ch	6	12	5	7	8	11	2	1	4	9	10	3
Cr	6	9	11	2	8	1	3	7	4.5	4.5	10	12
Re	10	4	6	2	8.5	8.5	2	2	7	5	11	12
Pf	8	10	9	1	2	5	3	6	4	7	11	12
Me	8	10	5	1	11	12	4	9	2	6	3	7
Ca	3	8	10	4	6	1	11	12	7	2	9	5
De	2	1	3.5	10	3.5	7	11	6	12	5	9	8
Hi	2	1	3	10	8	7	12	9	6	5	11	4
Kr	4	3	9	1	2	6	10.5	7.5	7.5	10.5	5	12
Ta	4.5	2	3	10	6	9	4.5	7	12	1	11	8
Av.	4.6	5.1	6.0	5.7	6.5	7.0	7.5	7.4	6.5	6.1	7.9	7.7
A.D.	*2.3*	*3.2*	*2.1*	*4.2*	*2.9*	*3.0*	*4.0*	*2.4*	*2.1*	*2.3*	*2.8*	*2.7*
P.E.$_{t-0}$	*.51*	*.70*	*.46*	*.91*	*.64*	*.65*	*.87*	*.52*	*.46*	*.50*	*.62*	*.59*

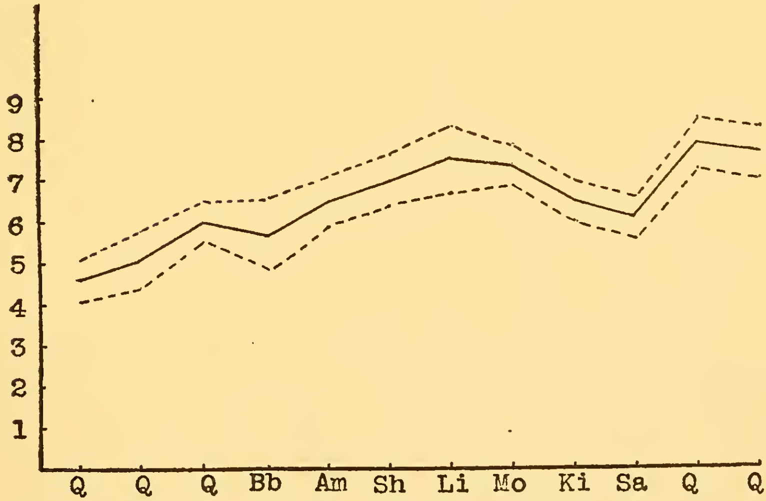

Fig. 8. Curve showing the relative ranking of the breathing rate scores. The order of the disturbances does not represent any time sequence.

TABLE XXI

RELATIVE RANKING OF TIME SCORES; NOISES IN THEIR CHRONOLOGICAL ORDER

Subjects	*Quiet*			*Noises*							*Quiet*	
Bl	11	10	5.5	5.5	8	12	4	9	7	3	1	2
Sp	11	12	8	10	7	5	9	6	4	2	3	1
Sa	12	10	4	9	6	2	1	3	11	7	8	5
Br	12	10	9	11	8	5	4	2	7	6	3	1
Bo	12	11	10	8	3	5.5	2	1	4	5.5	7	9
Ch	12	11	10	5.5	4	8	1	9	2	5.5	7	3
Cr	12	11	9	5	3	1	2	10	6	7	4	8
Re	8	3	4	12	1	2	10	11	6	9	5	7
Pf	9	10	6	12	11	7	2	8	3.5	1	5	3.5
Me	12	11	9	10	8	3	7	1	5	4	6	2
Ca	5.5	4	9	10	12	7	3	11	5.5	8	1	2
De	12	6.5	4	8	10.5	6.5	2	3	1	10.5	5	9
Hi	12	10	11	4	9	8	7	1	2	6	5	3
Kr	12	11	10	3	4	6	2	5	8	1	7	9
Ta	9	6	8	11	5	4	7	1	12	3	2	10
Av.	10.8	9.1	7.8	8.3	6.6	5.5	4.2	5.4	5.6	5.2	4.6	4.9
A.D.	*1.4*	*2.2*	*2.0*	*2.5*	*2.7*	*2.1*	*2.5*	*3.5*	*2.4*	*2.4*	*1.8*	*2.9*
P.E.$_{t-0}$	*.31*	*.48*	*.44*	*.54*	*.59*	*.46*	*.54*	*.76*	*.52*	*.52*	*.39*	*.65*

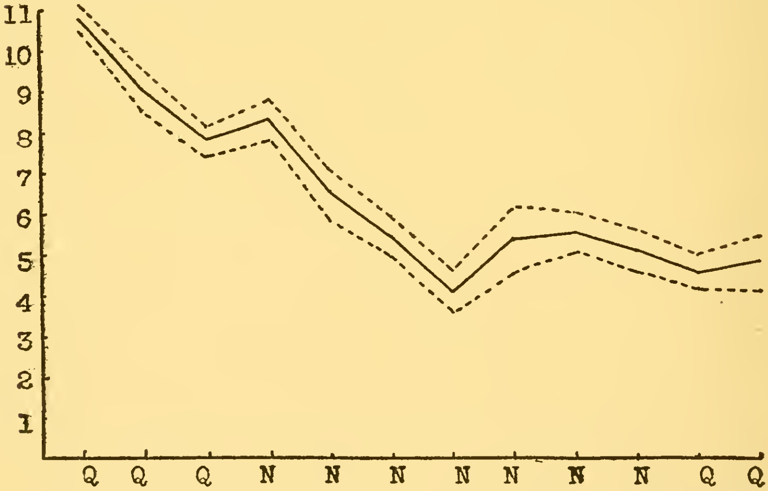

FIG. 9. Curve showing the relative ranking of the time scores with the noises in their chronological order represented along the base line.

theless significant. In several cases where the subjects were thus instructed it was noticed that the breathing records changed radically and in the manner that we had found was due to such lip movements. We then looked at the subjects through a small opening in the wall and found that they were moving their lips very slightly. When asked afterwards if they had done so, they all said they were not aware of having done so, showing that it is probable that subjects use this help in spite of themselves. The fact that changes in ratio occur (although not such radical changes) when there is no noticeable external movement seems to indicate

TABLE XXII

Relative Ranking of Key Pressure Scores; Noises in Their Chronological Order

Subjects	*Quiet*			*Noises*							*Quiet*	
Bl	12	3	5	7	10	11	8	9	5	5	2	1
Sp	1	5	4	12	10	9	11	6.5	8	6.5	3	2
Sa	8	9	7	12	10	11	6	5	4	3	2	1
Br	12	10	2	9	7	6	4	11	5	8	3	1
Bo	1	2	3	8	10	12	11	5	6	7	9	4
Ch	12	10	2	9	1	6	11	8	7	5	4	3
Cr	12	10	11	8	9	6	3.5	2	1	5	3.5	7
Re	4	5	8.5	12	6	10	2	8.5	11	3	1	7
Pf	10	11	9	12	2	1	7	3	4	8	5	6
Me	1	3	9.5	11	6.5	6.5	9.5	12	5	4	8	2
Ca	12	7	5	11	10	6	2	8	4	9	1	3
De	7.5	1.5	1.5	7.5	5	11	12	9.5	9.5	6	3	4
Hi	12	9.5	5	11	9.5	4	6	3	8	2	1	7
Kr	9	4	2.5	12	10	11	7.5	7.5	5	6	1	2.5
Ta	11	2	1	5	4	8	10	6	9	12	7	3
Av.	8.3	6.1	5.1	9.8	7.3	7.9	7.4	6.9	6.1	6.0	3.6	3.6
A.D.	*3.6*	*3.1*	*2.4*	*1.9*	*2.7*	*2.6*	*2.8*	*2.4*	*2.1*	*1.9*	*2.0*	*1.8*
P.E.$_{t-0}$	*.79*	*.68*	*.53*	*.42*	*.59*	*.57*	*.61*	*.52*	*.46*	*.42*	*.44*	*.40*

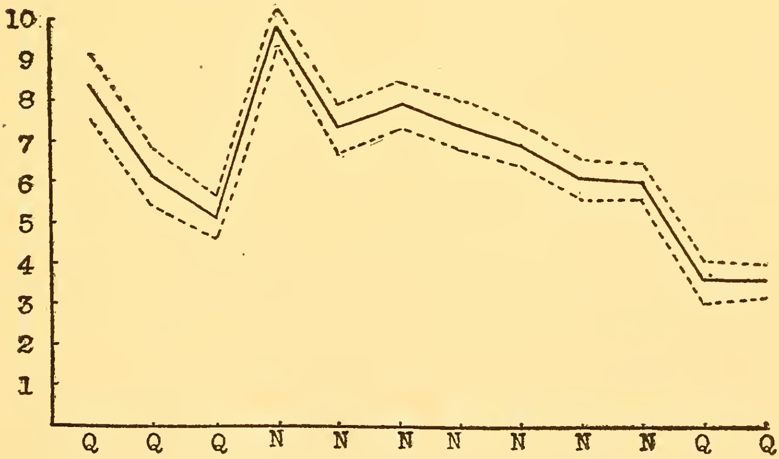

Fig. 10. Curve showing the relative ranking of the key pressure score with the quiet and noisy periods in their chronological order.

TABLE XXIII

RELATIVE RANKING OF BREATHING RATIO SCORES; NOISES IN THEIR CHRONOLOGICAL ORDER

Subjects	*Quiet*			*Noises*							*Quiet*	
Bl	10	6	2	9	12	7	8	11	5	3	1	4
Sp	2	1	3	6	11	4	12	10	9	8	7	5
Sa	2	3	7	8	9	11	12	5	4	10	1	6
Br	6	2	7	3	5	10	9	12	8	11	1	4
Bo	1	2	7	10	12	5.5	9	11	4	8	5.5	3
Ch	1	6	2	10	3	9	12	11	4	7	8	5
Cr	4	1	3	10	12	9	11	7	8	6	5	2
Re	1	2	5	9	5	11	12	5	10	8	3	7
Pf	3	10	1.5	6	1.5	4	9	8	7	5	12	11
Me	1	5	6	7	11	2	12	9	10	8	4	3
Ca	1	2	4	3	7	10	9	12	11	8	6	5
De	5	1	4	11	3	8	10	9	7	12	6	2
Hi	1	3	4	9	7.5	11	7.5	5	10	12	6	2
Kr	1	5	8	2	6	7	3	4	10	12	9	11
Ta	11	2	1	5	4	8	10	6	9	12	7	3
Av.	3.3	3.4	4.3	7.2	7.3	7.8	9.7	8.3	7.7	8.7	5.4	4.8
A.D.	*2.6*	*2.0*	*1.9*	*2.5*	*3.1*	*2.4*	*1.8*	*2.5*	*2.1*	*2.2*	*2.3*	*2.1*
P.E.$_{t-0}$	*.57*	*.44*	*.41*	*.54*	*.68*	*.52*	*.39*	*.54*	*.46*	*.48*	*.50*	*.46*

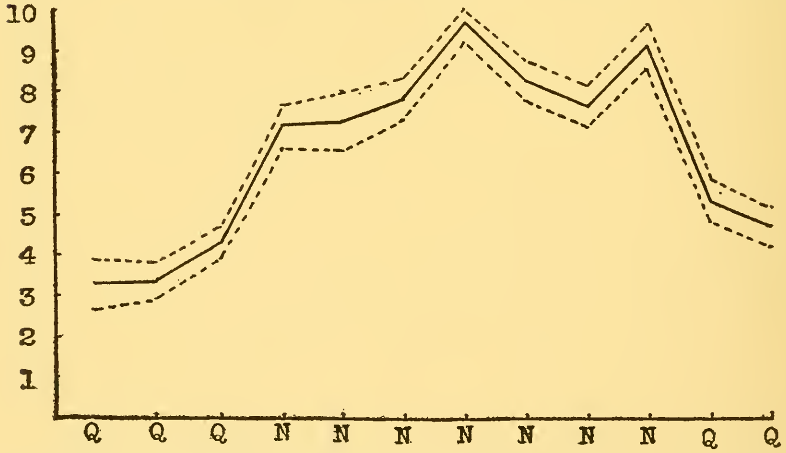

FIG. 11. Curve showing the relative ranking of the breathing ratio scores with the quiet and noisy periods in their chronological order.

that even faint movements of the inner organs of articulation have the effect of increasing the breathing ratio.

In Tables XXI, XXII, XXIII and XXIV we have arranged the relative ranking of these same scores chronologically. In each of the tables the first three columns represent the first quiet period of three hundred reactions; the next seven columns are the noises in the order in which they were presented for each subject; the last two columns represent the last quiet period. Below are the averages, average deviations and probable errors.

Despite the fact that with this arrangement the different noises are averaged together we get some significant results. The time record outside of a retardation at the beginning of the noises shows a continual drop till the middle of the disturbance period when it strikes a level. The drop is doubtless due to practise, for in this

TABLE XXIV

Relative Ranking of Breathing Rate Scores. Noises in Their Chronological Order

	Quiet			*Noises*							*Quiet*	
Subjects												
Bl	6	4	5	12	11	7	2	9	10	1	3	8
Sp	1	4	3	2	5.5	11	12	10	7	8.5	8.5	5.5
Sa	2	4	5	3	7	8	12	11	1	9	6	10
Br	6	2	7	3	5	10	9	12	8	11	1	4
Bo	1	2	6	3	8	11	4	12	7	9.5	9.5	5
Ch	6	12	5	1	2	4	7	9	8	11	10	3
Cr	6	9	11	1	4.5	7	8	2	3	4.5	10	12
Re	10	4	6	2	8.5	8.5	7	2	2	5	11	12
Pf	8	10	9	1	7	3	6	4	5	2	11	12
Me	8	10	5	2	9	1	12	6	11	4	3	7
Ca	3	8	10	6	11	2	7	12	1	4	9	5
De	2	1	3.5	6	5	10	11	7	3.5	12	9	8
Hi	2	1	3	7	9	8	5	6	10	12	11	4
Kr	4	3	9	1	6	10.5	7.5	2	10.5	7.5	5	12
Ta	4.5	2	3	1	12	6	9	7	4.5	10	11	8
Av.	4.6	5.1	6.0	3.4	7.4	7.1	7.9	7.4	6.1	7.4	7.8	7.7
A.D.	*2.4*	*3.1*	*2.1*	*2.3*	*2.2*	*2.7*	*2.4*	*2.9*	*4.6*	*3.2*	*2.9*	*2.7*
P.E.$_{t-0}$	*.52*	*.68*	*.46*	*.5*	*.5*	*.6*	*.5*	*.6*	*1.0*	*.7*	*.6*	*.6*

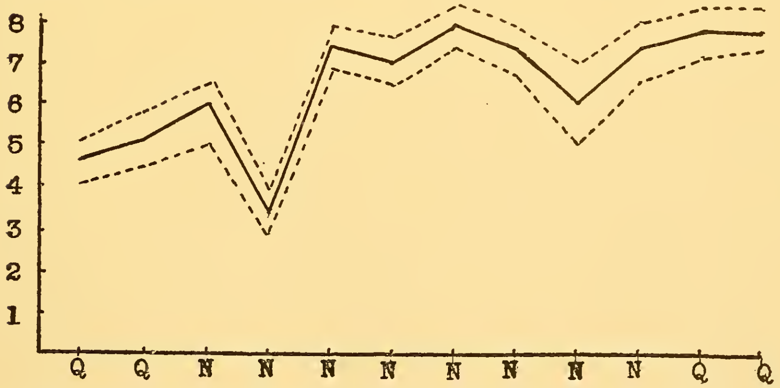

Fig. 12. Curve showing the relative ranking of the breathing rate scores with the quiet and noisy periods in their chronological order.

set of experiments instead of giving a practise period of four hundred reactions as we did in the earlier experiments, we gave only three hundred. It is significant to see that the curve drops regardless of the noises till the level is reached, which level is kept during the noises as well as during the ensuing quiet. Certainly if we had nothing but a time record we would have to conclude the noises had very little effect upon the work.

When we look at the key pressure and breathing ratio records we get a different story. The noises cause a marked increase of key pressure at the first. The pressure then decreases gradually, but remains much higher all through the disturbance period than it is after the noises stop. While the breathing ratio also increases at the beginning of the noise period, it reaches its maximum at the middle. The breathing rate when taken as a whole shows a gradual decrease. This is probably due to an outside factor. When the subjects began work it was just after climbing three flights of stairs. This bodily exertion followed by a period of almost complete physical inactivity probably is the cause of this general change in the breathing rate. One change that does seem significant, although taken by itself probably it would not prove anything definite, is the fact that at the beginning of the noise the rate increases. This with the other evidence we have is doubtless indicative of the exciting effect of the first introduction of the noises.

These four records bear out precisely our former findings, and show that the case with the majority of the subjects is somewhat as follows:

When the noises first come on they experience a disorientation which affects the time score somewhat. They then strain to overcome the effect of the disturbance and cast about for some help. While some hit upon articulation at the start, a large number do not do so until the disturbance has been going for some time. When they adopt this help and find they are making as good time they do not have to strain quite so hard, although they are under a greater tension by far than during quiet.

These tables also show that the effects of different noises are not so different as one might suppose. It is more a case of meeting a new situation, orienting oneself properly and adapting oneself to the new condition. We can not say just how much effect a certain noise will have, but we can say that when a disturbance comes it will be definitely met and combated. This overcoming may be through extra strain, using some factor that before was not utilized, or the using of some factor that was used before but now to a greater degree, or it may be through the combination of both the strain and the outside help.

Summary.—The experiments in this chapter corroborate the findings of previous experiments and show that:

1. The time records taken by themselves are of little significance except that they show an initial retardation in the noise period.

2. The key pressure records show that greater effort was exerted throughout the noise period. This tension is greater with the harsh noises than with the graphophone records. The tables giving the chronological order show that the tension was greater at the beginning of the noise period than at the end.

3. The breathing ratios show also an increase throughout the noise period. A significant feature of this record is that it reaches its highest point about the middle of the noise period, indicating that it takes most of the subjects some time to discover the aid of articulation for overcoming the noise effects.

4. The breathing rate shows a significant increase at the beginning of the noise period.

5. These records taken together show that at the first intrusion of the disturbances the subject is confused (see time record), he is somewhat excited by the disturbances (breathing rate), and strains to overcome it (key pressure record). The attempt to overcome it in most subjects leads to articulation, which in the majority of cases is not struck upon as an aid at once. With the help of this strain and articulation the time effect of the noises disappears and the subject attains or even exceeds his former speed.

CHAPTER VII

RELATIVE SIGNIFICANCE OF CHANGES IN TIME AND FORCE

THE foregoing experiments seemed to show that the influence of certain conditions upon a person's response is not revealed by measuring the time consumed in performing identical tasks under the different conditions. We have seen that increasing one's effort and calling in aids to combat the more difficult situation are the more significant factors. Now the assumption at the basis of most of the work on the effect of conditions upon activity is that the force exerted by the subject is the same under all circumstances; that if the subject is instructed to do his best, he *will* do his best unless he is an unusually obstinate creature. If this is so, then the only factor left to change is the time factor; therefore any change in the time is indicative of the effect of the changed condition, and no change in time is evidence that the condition has no effect. This may be good reasoning in a purely physical or physiological experiment but it can not be shown to hold in a psychological experiment. For instance if one should take the gastrocnemius muscle of a frog, he could show that the contraction of the muscle is directly proportional to the stimulation. He could also show that it is inversely proportional to the load it has to lift. If instead of a simple muscle one should take a decapitated frog the situation would be a little more complicated. A little acid placed on the breast would cause a contraction of the leg. If the leg is held the pull will be stronger. If the restrained leg fails altogether to overcome the restraining force the other leg will be used, and if both are held convulsive movements of the whole body will result. Still greater would be the increase in response of a normal frog. To hold its legs and stimulate it as before with acid would cause a riot of responses. If the case is so complicated with a frog, why should a normal human being, in a psychological experiment, be classed as a simple gastrocnemius muscle.

In order to bring out the time and force relations, to see how each changes as the task becomes harder or easier, an experiment was devised in which all the factors could be accurately measured. The method, in brief, was to have the subject raise a measurable weight a measurable distance in a measurable time. From these three the force could be computed, and the relations observed between the responses to the varying weights. The movement used was the flexion of the arm. The handle, which the subject grasped for the pull, was about on a level with the diaphragm. The subject stood with the arm extended to the front and when the signal was given drew the handle to the body. He was told plainly that what was to be measured was not the quickness of his response to the signal, but the force with which he pulled the weight over the space. He was instructed to use all his force all the time.

It can be seen that such an experiment required a sturdy piece of apparatus. On a stout table whose top stood 111 cm. from the floor was arranged a pair of grooved oak boards in which ran a light carriage which operated electric contacts. To one end of this carriage was attached the rope leading to the handle which the subject grasped, while from the other end a rope passed over a stout iron pulley (which ran very freely) and was fastened to the weight holder. This weight holder was made so that the weights could be readily changed. A rope was attached from the weight holder through a spring to the floor, long enough to allow the carriage to move fifty centimeters. The electric contact which started the chronoscope was at the very beginning of the movement of the carriage, the contact which stopped it forty-six centimeters from the beginning. As the total movement possible was fifty centimeters it can be seen that the chronoscope was stopped before the end of of the movement. It was thought advisable to arrange it this way so that the subject would not tend to regulate his pull to the distance and slow up before the last contact was operated. The spring which connected the rope to the floor took up the shock that must come at the end of a rapid movement.

The time was measured by a Hipp Chronoscope, which was wired according to the method outlined by Dunlap,[1] was carefully tested and gave very accurate readings.

The weights were calibrated with great care, and counting the weight holder weighed 2001, 3105, 3546, 4660, 5106, and 6220 grams. We then had a definite distance over which the weights were to be moved, we knew exactly how heavy each weight was, and we could measure just how long each movement took.

Eleven men subjects took part in the first set of experiments, each subject making one hundred reactions in one session. Ten pulls were made with one weight and then the weight was changed. The order in which the weights were given was: 6220, 5106, 4660, 3546, 3105, 2001, 6220, 3105, 4660 and 6220. The time consumed in reading the chronoscope and in adjusting the contacts gave the subject a rest between each pull so that fatigue did not enter in to any noticeable extent. In the beginning of each experiment period the subject was allowed to make six pulls for which the readings were recorded as in the later trials but were not used in the averages presented in the tables. This was to give him an opportunity to adapt himself to the new task.

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[1] Dunlap, K., "The Hipp Chronoscope Without Armature Springs," *British Jour. of Psychol.*, 1912, *5*, 1–7.

For each set of ten the average time was found and the probable error by the formula:

$$\frac{\text{A.D. } .8543}{\sqrt{n}} \equiv \text{P. E.}$$

In Table XXV are given the time scores in sigma (thousandths of a second) with the probable errors below each average. In the second section of the table are given the averages for each weight used. It will be seen that as the weight was decreased the time dropped from 220.6 sigma to 190.7 sigma. After the abrupt increase of the weight from 2,001 to 6,220 grams the time rose to 216.2 sigma. On the reduction of the weight to 3,105 grams it again fell to 190 sigma, and as the weight was increased the time also rose. Moreover it may seem from the second part of the table that when all the measures for the different weights are averaged together there is a fairly regular change in time as the weights change.

Now this looks as though these time records were a perfectly good indication of the change of weight. The time for weight 5106 is the only exception to a general correspondence between the weight change and the time change. Suppose however that we take it for granted that the force used all through was the same, for the reason that we told the subjects to do their best. Suppose that on the basis of this assumption we measure the differences in the weights used through the differences in time. We shall get very different results from what we know to be the real weight differences.

The formulæ to use in such a case are two. The first is that the acceleration of a body is equal to twice the distance traversed divided by the square of the time consumed; assuming that the body starts from rest, as it did in this case. After we have the acceleration we can find the force in dynes by the second formula, which is; that force, in dynes, is equal to the product of the mass by the acceleration plus the product of the mass by the acceleration of gravity, or 980 centimeters per second.

$$\text{Acceleration} \equiv \frac{2 \times \text{space}}{(\text{time})^2}.$$

$$\text{Force} \equiv \text{Mass} \times \text{acceleration} + \text{Mass} \times 980.$$

Now if we suppose that the force used throughout was 12,500,000

TABLE XXV

Time Records for Weight-Pulling Experiments

	Weights									
Subjects	6220	5106	4660	3546	3105	2001	6220	3105	4660	6220
Ja	225.0	197.3	219.0	256.4	224.8	240.2	227.6	184.7	199.2	219.3
	5.1	*6.9*	*4.8*	*5.6*	*5.1*	*6.9*	*4.8*	*4.8*	*5.6*	*1.6*
Is	204.6	186.6	189.8	184.8	180.3	165.7	217.4	170.3	195.4	221.4
	2.4	*1.8*	*1.1*	*2.1*	*1.1*	*1.9*	*2.1*	*2.6*	*2.1*	*1.3*
Li	221.6	187.7	187.5	192.3	177.5	154.3	194.8	166.7	184.7	195.2
	2.4	*1.8*	*2.0*	*2.2*	*2.4*	*1.5*	*2.1*	*2.8*	*2.6*	*1.7*
Si	261.3	245.7	229.8	220.9	212.2	206.7	222.1	225.9	250.3	259.3
	2.7	*5.4*	*1.9*	*1.7*	*1.1*	*2.7*	*1.3*	*2.4*	*2.5*	*3.6*
Wi	180.3	168.0	162.0	150.6	154.3	136.4	171.6	132.3	152.5	162.3
	1.7	*1.1*	*1.6*	*1.6*	*1.6*	*1.0*	*1.3*	*1.1*	*1.2*	*1.8*
Bn	180.6	161.3	156.1	140.7	161.0	163.0	192.5	156.6	181.2	191.9
	2.7	*2.4*	*1.9*	*3.3*	*1.8*	*3.0*	*3.1*	*4.8*	*2.8*	*2.6*
Sr	198.7	189.5	185.6	168.2	175.1	162.8	199.5	177.5	200.1	231.5
	2.5	*2.8*	*2.3*	*1.0*	*2.6*	*3.1*	*2.2*	*4.2*	*4.7*	*2.8*
Ke	315.9	262.4	302.2	318.9	329.4	319.4	314.9	321.6	355.6	356.4
	7.7	*4.2*	*4.4*	*6.8*	*7.4*	*8.1*	*4.6*	*6.0*	*6.0*	*5.2*
Bh	204.4	213.1	202.2	188.4	186.3	190.8	231.9	190.9	211.1	227.0
	2.0	*2.0*	*1.2*	*2.3*	*0.9*	*2.2*	*2.5*	*2.6*	*1.8*	*1.8*
Hn	217.2	213.7	198.1	176.3	169.8	155.6	181.8	157.4	176.1	188.0
	2.3	*6.0*	*1.6*	*2.8*	*1.0*	*1.4*	*1.6*	*1.2*	*3.4*	*1.8*
Sl	216.6	212.6	231.3	223.2	222.0	202.9	224.7	206.7	230.4	238.4
	1.7	*3.1*	*2.5*	*3.8*	*3.5*	*2.8*	*2.0*	*2.1*	*3.3*	*3.0*
Av.	220.6	203.4	205.8	201.9	199.3	190.7	216.2	190.0	212.4	226.4
Av. of P.E.s	*3.0*	*3.4*	*2.3*	*3.0*	*2.6*	*3.1*	*2.5*	*3.1*	*3.3*	*2.5*

Above Data Arranged According to Weights

	Weights					
Subjects	6220	5106	4660	3546	3105	2001
Ja	223.9	197.3	209.1	256.4	204.7	240.2
Is	214.4	186.3	192.6	184.8	175.3	165.7
Li	203.8	187.7	186.1	192.3	172.1	154.3
Si	247.6	245.7	240.0	220.9	219.0	206.7
Wi	171.4	168.0	157.2	150.6	143.3	136.4
Bn	188.3	161.3	168.6	140.7	158.8	163.0
Sr	209.9	189.5	192.8	168.2	176.3	162.8
Ke	329.1	262.4	328.9	318.9	325.5	319.4
Bh	221.1	213.1	206.6	188.4	188.6	190.8
Hn	195.7	213.7	187.1	176.3	163.6	155.6
Sl	226.6	212.6	230.8	223.2	214.3	202.9
Av.	221.1	203.4	209.1	201.9	194.7	190.7

dynes, which is about the average force we found actually used, and from the times compute the weights used we will get the following:

Time	Weights Found	Actual Weights
190.7	3550	2001
194.7	3670	3105
201.9	3860	3546
209.1	4040	4660
203.4	3910	5106
221.1	4370	6220

This shows at once the fallacy of depending on time measures to find the changes in conditions. The actual weights varied from 2,001 to 6,220 grams, the heavy one being three times the lightest one, there being an actual difference of 4,219 grams. In the weights found from an experiment based on the assumption of equal force being used the weights varied from 3,550 to 4,370 grams, an actual difference of only 820 grams, the heaviest being only 1.23 times the lightest.

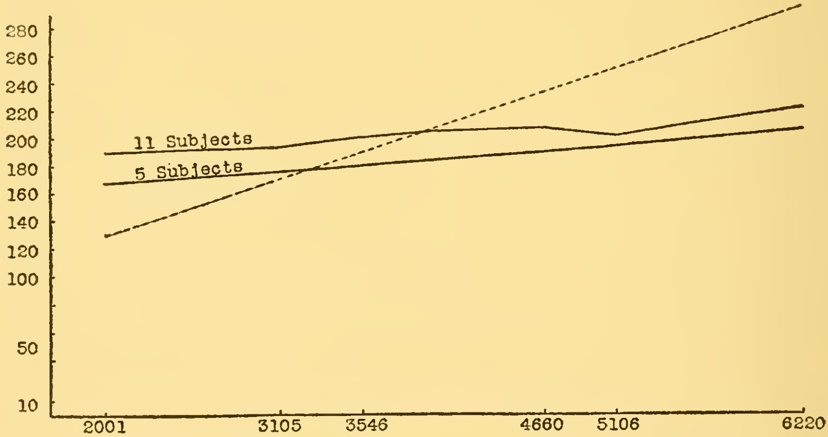

FIG. 13. Graph to illustrate the significance of time measurements. The height of the curve represents time in sigma. The divisions along the base the various weights used. The dotted line represents the times that would be required to raise the different weights 46 cm. if the force used was constantly 12,500,000 dynes. The solid lines represent times that were required in actual experiments. Each line is the result of a different experiment.

The thing may be expressed a little differently. In Fig. 13 the dotted line represents by its distance from the base the time that it would take to pull up the weights represented at the base if the force used throughout was 12,500,000 dynes. The solid lines represent the times that were actually consumed in pulling up the given weights. (The line marked "five subjects" represents the

TABLE XXVI

Force Records for Weight-Pulling Experiment

	Weights									
Subjects	6220	5106	4660	3546	3105	2001	6220	3105	4660	6220
Ja	17.35	17.02	13.50	8.44	8.70	5.17	17.10	11.44	15.40	17.95
	.50	*.75*	*.40*	*.22*	*.29*	*.20*	*.51*	*.43*	*.63*	*.19*
Is	19.70	18.55	16.40	13.03	11.81	8.72	18.20	12.88	15.80	17.70
	.33	*.25*	*.15*	*.22*	*.09*	*.15*	*.25*	*.32*	*.24*	*.14*
Li	17.64	18.30	16.75	12.30	12.10	9.78	21.20	13.30	17.18	21.10
	.24	*.25*	*.27*	*.23*	*.22*	*.15*	*.33*	*.35*	*.36*	*.26*
Si	14.42	12.75	12.65	10.17	9.43	6.32	17.62	8.62	11.40	14.60
	.16	*.32*	*.14*	*.11*	*.06*	*.12*	*.13*	*.12*	*.14*	*.25*
Wi	23.55	21.65	20.90	17.90	15.08	11.82	25.46	19.35	23.05	27.80
	.30	*.22*	*.30*	*.28*	*.25*	*.16*	*.32*	*.27*	*.28*	*.49*
Bn	23.60	22.95	22.20	19.60	14.08	8.94	21.50	14.70	17.60	21.60
	.54	*.49*	*.44*	*.58*	*.22*	*.24*	*.48*	*.74*	*.42*	*.40*
Sr	20.50	18.00	17.00	15.02	12.35	8.95	20.45	12.10	15.26	16.70
	.39	*.41*	*.31*	*.14*	*.24*	*.25*	*.34*	*.43*	*.53*	*.18*
Ke	11.95	11.80	9.11	6.67	5.68	3.78	11.83	5.80	7.97	10.56
	.29	*.21*	*.14*	*.14*	*.11*	*.10*	*.17*	*.11*	*.11*	*.13*
Bh	19.70	15.35	14.86	12.65	11.30	7.04	16.70	10.85	14.15	17.15
	.27	*.19*	*.12*	*.24*	*.08*	*.10*	*.22*	*.23*	*.16*	*.18*
Hn	18.15	15.30	15.30	14.00	12.90	9.65	23.35	14.55	18.40	22.25
	.25	*.58*	*.19*	*.40*	*.13*	*.14*	*.28*	*.19*	*.52*	*.32*
Sl	18.20	15.40	12.40	10.03	8.85	6.45	17.40	9.75	12.60	16.15
	.15	*.29*	*.16*	*.24*	*.19*	*.12*	*.21*	*.14*	*.21*	*.26*
Av.	18.61	17.01	15.55	12.71	11.12	7.87	19.16	12.12	15.35	18.51
Av. of P.E.s	*.31*	*.36*	*.24*	*.25*	*.16*	*.16*	*.29*	*.30*	*.33*	*.25*

Above Data Arranged According to Weights

	Weights					
Subjects	6220	5106	4660	3546	3105	2001
Ja	17.47	17.02	14.45	8.44	10.07	5.17
Is	18.53	18.55	16.10	13.03	12.34	8.72
Li	19.98	18.30	16.96	12.30	12.70	9.78
Si	15.54	12.75	12.02	10.17	9.02	6.32
Wi	25.60	21.65	21.98	17.90	17.22	11.82
Bn	22.23	22.95	19.90	19.60	14.39	8.94
Sr	19.22	18.00	16.13	15.02	12.22	8.95
Ke	11.45	11.80	8.54	6.67	5.74	3.78
Bh	17.85	15.35	14.50	12.65	11.07	7.04
Hn	21.25	15.30	16.85	14.00	13.72	9.65
Sl	17.25	15.40	12.50	10.03	9.30	6.45
Av.	17.85	17.01	15.45	12.71	11.62	7.87

results of an experiment to be described presently.) It can be seen that the two do not by any means coincide. The times have a tendency to equality showing that the subject tends to keep constant the time for pulling the weights at the expense of the force.

In order to see more clearly the significance of the force exerted let us look at Table XXVI. This table represents the force used by the eleven subjects in pulling up the weigths as described above, the unit being one million dynes. In the second part of the table the totals for each weight for each subject are given. These forces were obtained by the use of the two formulæ given above. It is evident that the force used varies more significantly than the time. In Fig. 14 we give in the dotted line the force that would need to be exerted if the time were kept at 205 sigma throughout the experiment. It will be seen that the solid lines, which represent the actual force used for the various weights, more nearly follow the dotted line than did the time line in Fig. 13. In other words the subjects tend to change the force used in order to keep the time nearly constant.

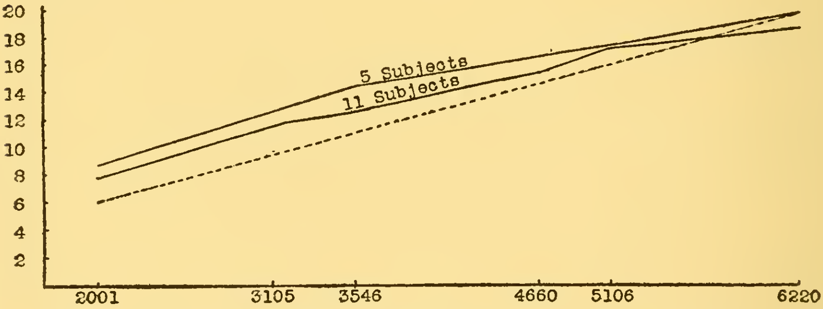

FIG. 14. Graph to illustrate the significance of force measurements. The height of the curve represents force in million dynes, the divisions along the base the various weights used. The dotted line represents the force that would be required to raise the different weights if the time were constantly kept at 205 sigma. The two solid lines represent the forces that were actually used by subjects in two different experiments.

We may mention another feature of the experiment that illustrates this point. As we decreased the weights by degrees the subjects decreased their force considerably. In three casees out of the eleven this decrease was so great that, when the weight was changed from 2,001 to 6,220 grams, the force they were using was not sufficient to pull up the heavy weight, and they failed to make a score. In those cases where they did pull it up, it invariably took a longer time than the second pull with the heavy weight. We will give the times for the first and second pulls on the 6,220 weight immediately following the 2,001:

	First Pull		Second Pull	
Subject	Time	Force	Time	Force
Ja	268	14.6	244	15.7
Is	330	11.3	191	21.7
Li	297	12.4	183	23.7
Si	failed	6.1 or less	222	17.7
Wi	208	20.3	176	24.5
Bn	279	13.4	193	21.4
Sr	353	10.6	201	20.2
Ke	failed	6.1 or less	269	14.0
Bh	248	15.4	218	18.1
Hn	246	15.5	166	26.8
Sl	failed	6.1 or less	227	17.2

These first reactions were not counted in the averages given in the table. We always gave eleven pulls on the heavy weight following the lightest. They were kept separate and are given here to show that the subjects adjust their energy to the difficulty of the task. The subject works at a regular rate thinking that he is doing his best, but when the increased weight comes, he buckles down and tries to keep up his former pace.

One more incident in connection with this experiment is worthy of note. Subject Si in his very first pull made a score with the weight 6,220 grams of 100 sigma. He threw himself into it with all his might. When it came up so quickly he expressed his surprise that the weight was no heavier, and his next trial was 371 sigma. He was then told to do his best and pull all the time as hard as he did the first trial, but either he could not or would not, for his times range from 206 to 261 sigma. This again goes to show that a subject expends energy in proportion to the idea he has of the difficulty of the task.

In order to make sure that the results of this experiment were not dependent upon the method of procedure we performed a second experiment, in which each subject made only ten pulls each day (and with the same weight) and worked only two periods a week. The first day the weight used was 3,542, the second 6,220, the third 2,002, and the fourth day 5,106 grams. There were five subjects, two women and three men. Both the time (in sigma) and force (unit of one million dynes) results of this experiment are given in Table XXVII, and the curves are plotted in Figs. 13 and 14. With a procedure of this nature we should expect more irregularity than in a one period method due to the fact that the subject may set a different pace for himself on different days on account of differences in physical or mental condition. This is actually so, and while the total averages show the same results as the single period method the individual cases present more irregularities.

TABLE XXVII

Scores for Weight-Pulling Experiment

(One Weight Used for each Sitting)

Time Scores

	Weights			
Subjects	3542	6220	2001	5106
Mg	231.0	241.7	212.7	212.4
	1.4	*3.0*	*1.8*	*0.7*
Vg	161.5	208.3	156.8	210.4
	1.5	*2.1*	*1.6*	*0.9*
Kd	225.1	234.4	190.9	210.4
	3.6	*2.0*	*3.1*	*1.3*
Gy	141.1	170.3	144.5	174.2
	2.5	*1.4*	*2.2*	*2.0*
Pn	146.2	187.5	139.2	177.1
	1.0	*1.4*	*1.4*	*1.3*
Av.	181.0	208.4	168.8	196.9
Av. of P.E.s	*2.0*	*2.0*	*2.0*	*1.2*

Force Scores

Subjects	3542	6220	2001	5106
Mg	9.11	15.80	6.03	15.40
	.07	*.24*	*.07*	*.07*
Vg	15.98	19.20	9.47	15.55
	.25	*.28*	*.16*	*.09*
Kd	9.42	16.43	7.00	15.55
	.21	*.18*	*.17*	*.12*
Gy	19.55	25.70	10.68	20.40
	.44	*.35*	*.22*	*.34*
Pn	18.62	22.25	11.21	19.88
	.18	*.24*	*.19*	*.22*
Av.	14.53	19.87	8.88	17.36
Av. of P.E.s	*.23*	*.26*	*.16*	*.17*

In tests where the influence of some factor has been the object of investigation one method has been to endeavor to keep the subject in ignorance of the change in condition. Drug doses have been intermingled with fake doses, temperature and humidity of the air have been subtly changed, and disparate stimuli of various sorts have been unexpectedly introduced. The supposition has been that perhaps if the subject was aware of the change he would accommodate himself to it, but that if he did not know it he could not so adjust his responses and so any change, or lack of change, in time would be the measure of the change of conditions. In this last experiment the subjects did not know that the weights were changed from day to day. When questioned after the experiment was completed they said that they could not tell, that they could not remember from one test to the other how heavy the weight had been. They had no idea of the changes of the weights and yet their results show that they tended to keep their time scores the same and to adjust the force used to the weight to be pulled.

This tendency of the subject to keep a constant time irrespective of the force required holds for subjects varying greatly as to the force used. For instance with the heaviest weights the force used varied from 10 to 27 million dynes, yet each subject tended to keep his time constant throughout. Whatever pace he set in the beginning he tried to keep. The recognition of such a motor set is not new to psychology. Müller and Schumann[2] and a number of later writers have discussed in detail the "Einstellung," or motor set; and its relation to judging of lifted weights has been elaborated by Miss Steffens.[3] Our experiment has brought out many of the same things that they have found. We have merely presented them with a different emphasis to bring out points relevant to and corroborative of our experiments with noise.

We believe that such a set is present in any test of mental or physiological work. A subject is placed in a certain situation, told to pull a weight, react to a visual exposure, or to do anything you please. If the situation is a new one he will at first be at a loss to know how fast to go, and will therefore adapt his speed to the conception of the task that he has derived from the instructions given. Different interpretations of the instructions will cause different subjects to start off at different speeds. After a short period of the work, sometimes only a few trials, they modify their imaged impression of the task and change their responses accordingly. If they thought the task was harder than it proved to be, they will decrease their speed when they learn its true nature. This is shown by the illustration cited of the man who on the first pull made a record of 100 sigma for the heaviest weight. When he found it

[2] Müller and Schumann, "Ueber die psychologischen Grunlagen der Vergleichung gehobener Gewichte" (Pfluger's *Arch. f. d. ges. Physiol.*, 1889, *45*, 37.

Binet, *Rev. philos.*, *29*, 143.

Delabarre, "Ueber Bewegungsempfindungen," Freiburg, 1890, 109.

Stein, Gertrude, "Cultivated Motor Automatism," *Psychol. Rev.*, 1898, *5*, 294.

Martin and Müller, "Zur Analyse der Unterschiedsempfindlichkeit," Leipzig, 1899.

[3] Steffens, Laura, "Ueber die motorische Einstellung," *Zeit. f. Psychol. u. Physiol. der Sinnes.*, 1900, *23*, 241–308.

was not as heavy as he thought it was his record fell to 370 on the second trial. If they start off too slowly they will increase. The pace toward which this adjustment tends is not in proportion to the strength of the individual, but rather toward a pace congenial to that individual, for we had several women who used more force than strong men, and the slowest record we give (subject Ke) was made by a stout man. Miss Stein[4] has made a study of the "motor automatisms" of people of different temperaments, showing that it is possible that every person has a pace congenial to him. It can not be said that if an individual is slow in a certain task he will be slow in every other, but it seems rather that in every task the subject sets his own pace. This varies also with the same task, although not as much as might seem probable; for it has been shown that learning, instead of being a process of increasing the speed of the same movements, is a substitution of more efficient movements for the older less efficient ones. It is possible to change the circumstances so much that a change in speed is almost inevitable, but in such a case the change in speed is not indicative of the *amount* of change in the situation.

It is very likely that individuals vary greatly as to the amount of opposition they present to any change in the pace set. We have some evidence of this in our figures. Suppose we take the differences in time taken by all our subjects in pulling up the heaviest weight and the lightest one, and arrange them in order from those who worked fastest to those who worked the slowest; we get the results seen in Table XXVIII.

If we group the above into three groups of five subjects each, eliminating one subject (Ja) who made slower time with the light weight than with the heavy, we find that the fastest group has an average difference of 34.9 sigma, the middle group an average difference of 45.4 sigma, and the slowest group 29.4 sigma. These figures however cannot be taken at their face value for the reason that a change of one sigma at high speed amounts to more than a like change at low speed. If we take the average time for each group and find the acceleration that a change in one sigma would make at this speed we find that for the fastest group a change of one sigma requires a change of acceleration of 40 cm. per second, one sigma change in the middle group a change of acceleration of 27 cm. per second, and in the slow group a change of acceleration of 13 cm. per second is required for one sigma change in time.

Since with the fastest group a change of acceleration of 40 cm. is required for every sigma change in time, an average change in time of 34.9 sigma would denote an average change in acceleration

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[4] *Loc. cit.*

TABLE XXVIII

SHOWING DIFFERENCES IN TIME BETWEEN THE HEAVIEST AND LIGHTEST WEIGHTS

Subject	Heaviest Weight, Sigma	Lightest Weight, Sigma	Difference	Average Differences for Three Groups
Gy	170.3	144.5	25.8	
Wi	171.4	136.4	35.0	
Pn	187.5	139.2	48.3	34.9
Bn	188.3	163.0	25.3	
Hn	195.7	155.6	40.1	
Li	203.8	154.3	49.5	
Vg	208.3	156.8	51.5	
Sr	209.9	162.8	47.1	45.4
Is	214.4	165.7	48.7	
Bh	221.1	190.8	30.3	
Ja	223.9	240.2	−16.3	
Sl	226.6	202.9	23.7	
Kd	234.4	190.9	43.5	
Mg	241.7	212.7	29.0	29.4
Si	247.6	206.7	40.9	
Ke	329.1	319.4	9.7	

for this group of 1,396 cm. In the middle group an average change in time of 45.4 sigma denotes an average change in acceleration of 1,226 cm.; while in the slowest group an average change in time of 29.4 sigma denotes an average change in acceleration of 382 cm. Since under similar conditions a change of acceleration is proportional to a change in force, evidently a person who sets a very slow pace maintains the greatest uniformity in speed regardless of conditions, doing it however with the least change in the output of energy. One who sets a very fast pace is not quite so uniform in speed when conditions are changed, but he changes his force most in trying to be uniform. One who sets a middle pace is most variable in speed, and is between the slow and fast subject in his efforts toward uniformity.

One might suppose that if a subject is urged to do his utmost in a test, that when the conditions were made more difficult, he would be less able to meet the change than one who worked more slowly; the supposition being that he would be nearer his maximum speed. Although the above calculations show that in response to changed conditions those who work the fastest do vary more than the slowest in time, they only vary 14 per cent. more, while they show a 272 per cent. greater variation in force. The slow worker is more easily influenced by his conditions than a fast worker although he may show it less. A fast pace does not mean that the worker is near his limit but that he is fired up to the work in hand, and that he will offer greater opposition to resistance than one who is not roused enough to work hard.

Summary.—In an experiment in which the space factor was constant and the time and energy could both be accurately measured, it was found that:

1. While changes in the work to be done caused corresponding changes in time, the time changes were no criterion upon which to calculate the changes in amount of work.
2. The general tendency is for a subject to keep his time score constant irrespective of the force required.
3. The force varies much more significantly than the time with changes in the task.
4. The "motor set" is therefore a time set rather than an energy set.
5. The greatest opposition to a change in pace is offered by those who set the fastest pace. One who sets a slow pace keeps the most uniform time but with the least opposition. One who sets a medium pace varies most in speed, and occupies a middle position in his efforts toward uniformity.

CHAPTER VIII

Summary and Conclusions

The first experimental studies in psychology were concerned very largely with time measurements. Reaction time and the speed of mental processes occupied most of the horizon for some time. Later the measurement of association time, the time required to perform a new motor act, learning time, the relation of time to memory processes, and the successful measurement of other cerebral processes in their time relations has broadened the scope and brightened the outlook for experimental psychology. At first the end of such investigations was to formulate the laws of mental life, and in this direction great success has been achieved. Compared with the recency of the attempts, no less remarkable has been the light that such work has thrown on individual differences. It is no wonder then, when the great cry for efficiency rang out, that psychologists should have endeavored to measure mental efficiency by utilizing the old time measurements.

In that portion of the investigation that has to do with selecting the best individuals from a group, psychology has been fairly successful, although this field is still ripe for workers. Time measurements are finely adapted to selecting the best individuals in a certain line. We want the man who can do the best work in the shortest time. While we can not say on the basis of any tests yet found who will best follow a certain occupation, yet we can select those who are fitted for the more exacting occupations of life.

When however we come to decide what conditions are conducive to the most efficient work we have met an entirely different problem. The difficulty lies in this: In measuring mental processes in order to find the laws governing their operation, or to study individuals or groups, it can be assumed that the individuals work with about the same effort; and if they do not, it makes no great difference, for in group measurements statistical treatment will take care of differences. In studying the effect of some external condition on work we must however be sure that the force exerted is a constant, or else measure any changes that it may undergo as a result of the changes in condition. To be sure if we simply wish to find out under what conditions we can get the most done regardless of cost, our problem is easy; but it is then a problem of greed and not one of efficiency.

The problem of determining the amount of energy required for any mental operation is one charged with such great difficulties that psychologists have been tempted to ignore it and to regard energy as a constant. Then on the basis of experiments resting on this assumption, they argue that there is no such thing as mental energy. Up to the present time no one has ever shown that a person does or even can keep his efforts constant during a task, and until this is proven we have no grounds for drawing conclusions from any experiment that takes for granted that it is a constant.

In the experiments which we have performed we first carried out a rigid test of the influence of noisy conditions upon the time required to do a certain task. We constructed a piece of apparatus that would enable us to escape any leak due to a faulty mechanism. We took records that would permit us to measure each response of the subject for an indefinite length of time with absolutely no intermission. In every way we tried to see to it that no conclusions could be drawn from data secured unfairly, yet as far as our time and accuracy records went we could only show that a seemingly unfavorable condition influenced the subject to a very slight extent and that after a slight retardation he exceeded the speed made under normal conditions, doing as accurate work under both conditions.

If we had been sure that the time was the only variable involved we should have rested satisfied with that conclusion no matter how paradoxical it might have seemed. We however had a little indication that the subjects struck a different attitude when they worked under noisy conditions. We therefore planned to experiment further in order to ascertain if possible in what this change consisted.

Breathing records were taken with twenty-five subjects. The comparison of the inspiration and expiration times during quiet and noisy conditions showed a constant relation. Examination seemed to show that this breathing change was due to articulation, which the subjects adopted as a means of overcoming the disturbing effect of the noises. While the changes were large in cases of noticeable articulation, in others where articulation was not noticeably present it nevertheless appeared when the breathing records were treated statistically. It may therefore well be that this factor has had something to do with the lack of correspondence between the work of different investigators on the changes of breathing due to mental processes.

The measurement of the pressure exerted upon the keys by the subjects in reacting showed that under noisy conditions the keys were struck harder than under quiet conditions, which seems to show that the subject strained harder under the noisy condition. This shows that while time and accuracy records do not suffer materially through the presence of irrelevant noises, yet there are other factors that do change as a result of this change in conditions. We do not on the basis of these experiments claim to have shown that a noisy condition is less efficient than a quiet one, but we have shown that nothing can be said as to the efficiency of any condition on the basis of time measurements alone. What time measures do show is whether or not a person is able to adapt himself to a new situation. If he is able to do so it shows the flexibility of the human organism, but it does not show anything about the condition itself.

Some critic whose eye is blinded by the intensity of practical considerations may discount the utility of what has been shown because we have not stated exactly the value of the extra force and help needed to combat the noises; but when one views the literature based on the assumption that time measures regardless of effort are a true measure of efficiency, one will be forced to admit that a question of method is in this particular case of more vital import than a numerical statement of the effects of certain noises. In the light of this investigation, when experiment shows that a person can do as much work at the end of twenty-four hours of hard work as at the beginning, that he can do just as good work under the influence of all sorts of drugs as when free from their influence, and that all sorts of distractions are unable to produce a slowing in the work of an individual; then we should conclude that a person is capable of adaptation or adjustment to all such conditions, but never from time measures alone can we derive any legitimate conclusion as to the advisability of working after long periods of labor, the influence of drugs, or the effects of distractions. Our conclusions must be conclusions regarding individual adjustment and not regarding the objective efficiency of conditions.

In all this we do not in the least mean to discount non-introspective methods of measuring the effect of external conditions. We believe that Professor Woodworth[1] was right in suggesting this method. He argued that a change in conditions should change the subject's response in some way that could be measured. We believe that this is a correct method, the mistake being simply that not all the changeable factors have been properly controlled and measured.

We tried another experiment to show more clearly the relations of time and force and their connection with adjustments to changes in conditions. It consisted in having the subject raise different weights with as much force as possible. The time was measured directly and the force computed from this measure together with the weight and the distance over which it was pulled. The results show that one tends to keep the time taken in the process constant regardless of the weight raised, and consequently to change the amount of force used in proportion to the weight. At the beginning each subject set his own pace and tended to keep that pace regardless of changes in the amount of effort required. A person does not compensate for changes in the situation by changes in the speed of the work but by changes in the effort put forth.

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[1] Woodworth, R. S., "The Accuracy of Voluntary Movement," *Psychol. Rev. Monog. Suppl.*, 1899, *3*, 25. Whole No. 13.

The need of controlling or measuring the energy factor has been felt among psychological investigators. Professor Dodge has squarely faced the problem and attempts to solve it by measuring the amount of metabolism in the neuron.[2] He states in a very clear manner the inadequacy of time measurements, and whether the measure of metabolism is the solution or not, he certainly makes it clear that something is needed besides time measurements. Thorndike[3] objects that measurements of metabolism are from their very nature isolated from measures of product yielded. He proposes instead a measure of satisfyingness. The subjects as they work are to make an introspective record of how satisfying the work is and grade it on an arbitrary scale. He has not however shown that satisfyingness or unsatisfyingness can be a measure of effort. No correlations have ever been produced that would make any such a test an adequate measure of effort. It is less capable of combination with product than would be a measure of metabolism and would be far less accurate. Of course it involves less difficulty as far as technique is concerned and that may be a consideration, but hardly a legitimate one where the facts are wanted. While we did not try to get any scale of satisfyingness in our experiments, we did, as stated in Chapter V, ask every subject how he liked the experiments and all except two said they enjoyed it. The two exceptions make slower time scores during the noises. We believe that satisfyingness would correlate higher with ability to maintain speed in accordance with the pace set by the subject than with the amount of effort required. To expend extra effort is not of itself unsatisfying. On the contrary, if it accomplishes what is desired it is very satisfying. None of the subjects found it any more satisfying to pull the light weight than the heavy one.

The need of controlling or measuring the energy factor has certainly been made clear by our experiments. We have shown that to changes of situation the subject adapts himself by changes in effort put forth. We have shown that to cause a retardation of

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[2] "Mental Work, A Study of Psychodynamics," *Psychol. Rev.*, 1913, *20*, 1–42.

[3] Thorndike, E. L., "Educational Psychology," Vol. III, 1914, p. 116.

16.3 per cent. in time requires a change of 300 per cent. in the difficulty of the task. In the case of noises the time was not increased at all, was even in some cases decreased, and yet it was shown that the subject did use greater effort and had to call in the help of the organs of articulation. In the light of these findings we need to revise some conclusions as to fatigue, the effects of drugs and distractions, and other changes in the conditions under which subjects work. A change in condition may cause large changes in force before any change in time is apparent, and where such change is seen it signifies in all probability a much greater change in force.

The conclusions we have reached may be briefly summarized as follows:

A. *As to the Effect of Noises on Activity.*

1. The initial effect of noise is to retard the speed of work.
2. After this initial retardation there is an increase in speed. In many cases the subject exceeds the speed he had attained before the introduction of the noises.
3. Extra effort is put forth to overcome the noises. This is shown by an increase in the pressure exerted upon the keys in reacting. This extra effort continues pretty uniformly throughout the noisy period.
4. Articulation is used as a means of overcoming the effect of the noises. This articulation is shown by changes in the breathing of the subject. In some cases this help is not used immediately after the introduction of the noises, showing that it is an adjustment that is more deliberate than the extra expenditure of energy.
5. It is by means of these helps that the subject is able to eliminate the influence of noises from his time score and the extent of the use of these is more a measure of the effect of the noises than is the time record.

B. *As to method.*

1. Time measurements serve to indicate facts concerning the laws of mental operation, individual differences and class comparisons, but they do not serve to show whether one condition is better or worse than another.
2. In order to know whether a condition is efficient or not we must have evidence of either the constancy or change in effort. To take for granted that it is constant is to make an unwarranted assumption, and destroys the validity of any conclusions as to efficiency.
3. Tests taken without the knowledge of the subject, but

directly connected with the work in hand, give the most promise of success as indexes of change in effort expended.

C. *As to Time and Energy Relations.*

1. In a test where numerical comparisons were possible it was found that energy changes are much more significant than time changes.
2. A person tends to change the amount of energy expended to meet changing situations, and to keep the time constant regardless of variations in conditions.
3. We offer as a statement of the situation that *any real or imagined change in the resistance offered to the maintenance of a set causes a change in the output of energy.*

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